EXHIBIT 1

FILED
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KING COUNTY
SUPERIOR COURT CLERK
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CASE 19-2-28930-9 SEA

IN THE SUPERIOR COURT OF THE STATE OF WASHINGTON
IN AND FOR THE COUNTY OF KING

PACKAGING CORPORATION OF AMERICA, Plaintiff, v. LUNDBERG, LLC f/k/a A.H. LUNDBERG ASSOCIATES, INC. and A.H. LUNDBERG SYSTEMS LTD., Defendants.	No. 19-2-28930-9 SEA **FIRST AMENDED COMPLAINT FOR:** **(1) PRODUCT LIABILITY – NEGLIGENCE;** **(2) PRODUCT LIABILITY – STRICT LIABILITY;** **(3) NEGLIGENCE;** **(4) BREACH OF IMPLIED WARRANTY – FITNESS FOR A PARTICULAR PURPOSE;** **(5) BREACH OF EXPRESS WARRANTY;** **(6) FRAUD; AND** **(7) UNFAIR AND DECEPTIVE BUSINESS PRACTICES.** **JURY DEMAND** Date Action Filed: October 31, 2019

Plaintiff Packaging Corporation of America ("PCA") complains and alleges causes of action against Lundberg, LLC f/k/a A.H. Lundberg Associates ("Lundberg"), Inc. and A.H. Lundberg Systems Ltd. ("LSC") (collectively, the "Lundberg Defendants") as follows:

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INTRODUCTION

1. For over 50 years the Lundberg Defendants have been considered leading engineering and system experts for equipment and processes designed specifically for paper and pulp mills. An integral aspect of the Lundberg Defendants' business has been designing, manufacturing, installing, and maintaining systems that evacuate non-condensable gases that may be combustible from the paper and pulp mill environment. The Lundberg Defendants share ownership of certain intellectual property, share operating names and common identifies even if separate entities, and shared design and manufacturing at points in time. The Lundberg Defendants' systems include ones that transport non-condensable gases that require specific safety devices to be installed to mitigate the risk of flammability and explosion. One of these safety devices is known as a flame arrester, and it is designed to stop the propagation of a flame throughout the system by stopping its transmission from one side of the flame arrester to the other side of the flame arrester. A flame arrester is an integral part of the Lundberg Defendants' systems and serves as a critical safety device used to stop flames spreading within the system.

2. For many decades, the Lundberg Defendants have been designing, manufacturing, installing, assembling, selling, marketing, and maintaining proprietary design flame arresters for use in these systems ("Lundberg Flame Arresters"). The Lundberg Defendants actively promote on their websites and in marketing materials the installation of the Lundberg Flame Arresters in systems as a critical safety device or safety system component. The Lundberg Defendants have placed hundreds, if not thousands, of Lundberg Flame Arresters into commerce and installed and maintained them at pulp and paper mills across the United States and internationally, including at PCA's mills.

3. It was recently discovered that contrary to representations and warranties made by the Lundberg Defendants for years, and contrary to the expectations and standards in the industry, the Lundberg Flame Arresters were never tested and were never certified under any applicable standards. This very basic and highly material information was never disclosed by the Lundberg Defendants to the pulp and paper mill industry, despite, for example, Lundberg being present at

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PCA's paper and pulp mills regularly and working on its systems that include the Lundberg Flame Arresters for decades. This material information was actively concealed from PCA and the industry by the Lundberg Defendants. The Lundberg Defendants also actively concealed that the Lundberg Flame Arresters were designed differently than other flame arresters that were tested and certified and in use in the industry, and also actively concealed that the Lundberg Flame Arresters in fact did not prevent the transfer of flame from one side to the other of the purported safety device. Put bluntly, the Lundberg Defendants concealed that the Lundberg Flame Arresters did not work. Because it is not apparent from regular usage or on the face of the Lundberg Flame Arresters, the latent defects in the Lundberg Flame Arresters went undetected by PCA.

4. After discovering that Lundberg Flame Arresters were never tested and were never certified to any applicable standards, in 2018 PCA sent a Lundberg Flame Arrester that it had purchased directly from Lundberg in or around November 2017 for offsite testing by an independent third-party facility. That Lundberg Flame Arrester completely failed to operate as represented—it failed to mitigate any flame passage from one side of the safety device to the other side. At great cost, PCA then removed all Lundberg Flame Arresters from the company's mills and replaced these critical safety devices with new flame arresters that were designed, manufactured, tested, and certified to applicable standards by parties not involved in this litigation. This replacement program included significant engineering and system work, again done by parties not involved in this litigation because PCA had completely lost confidence in the integrity and capability of Lundberg.

5. Again, at great cost, PCA sent multiple Lundberg Flame Arresters of varying sizes that had been installed at its mills and removed in 2018 for off-site testing by the same leading, independent, third-party testing facility. During testing in 2019, none of the Lundberg Flame Arresters worked as designed, manufactured, and/or marketed by the Lundberg Defendants; none prevented the spread of flame from one side of the device to the other side; none operated as a safety component as represented by the Lundberg Defendants; and none operated as would be expected by PCA and the industry for a critical safety device. Surprisingly, the Lundberg Flame

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Arresters actually accelerated the flame, increasing the velocity and therefore magnitude of an explosive event.

6. As specialty engineering and system design firms that hold themselves out as experts in the pulp and paper mill industry, the Lundberg Defendants have dominated the paper and pulp mill industry for decades and their products are universally used and generally regarded as safe and state of the art. But it is now known that at least one of the Lundberg Defendants' products are untested, defectively designed, uncertified, and completely unable to perform their intended purpose.

7. PCA seeks to recover all costs associated with (1) purchasing, installing, and maintaining the Lundberg Defendants' systems; (2) evaluating and completing engineering and upgrades to the systems designed, manufactured, assembled, installed, marketed, sold, and maintained by the Lundberg Defendants; and (3) testing the Lundberg Flame Arresters for latent defects and replacing the defective Lundberg Flame Arresters. PCA also seeks costs and fees for bringing this action, as well as treble damages due to Lundberg's fraudulent, unfair, and deceptive business practices.

THE PARTIES

8. PCA is a publicly traded Delaware corporation with its principal place of business in Lake Forest, Illinois. PCA is a leading manufacturer of paper and pulp products and has business operations in 29 states as well as Canada. In Washington State, PCA operates in four locations: Wallula, Richland, Auburn, and Algona.

9. Lundberg, LLC ("Lundberg") is headquartered and conducts its principal operations in King County, Washington. With over 80 years of experience, Lundberg was founded and named after Algeria Harvard Lundberg (A.H. Lundberg). Lundberg is a leading engineering and equipment supplier in the pulp and paper industry, wood products industry, and many other process industries. Several of the products at issue in this case were designed, manufactured, assembled, installed, marketed, sold, and/or maintained by Lundberg in the state of Washington. For years, A.H. Lundberg Associates, Inc., founded in the 1950s, jointly owned and operated a

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company with offices in British Columbia, Canada, to serve the Canadian pulp and paper industry, and that company was known as Lundberg Ahlen Equipment Ltd. In or about 2016, A.H. Lundberg Associates, Inc. was acquired by Dustex LLC, and a new company operating as Lundberg, LLC took over all of the operations of the previous company. Lundberg, LLC has as its sole member Dustex LLC. Dustex LLC has as its sole member Dustex Investment Holdings LLC. Dustex Investment Holdings LLC has as its sole member Dustex Solutions LLC. Dustex Solutions LLC has as its sole member Dustex Holdings LLC. Dustex Holdings LLC has as its members three limited liability companies and an individual; one of the limited liability companies is Dustex Investment Resources LLC. Dustex Investment Resources LLC has as its members three limited partnerships and a corporation. The corporate member is Dustex (TE) III Blocker Corporation, which is a holding company with no business operations.

10. On information and belief, A.H. Lundberg Systems Ltd. ("LSC") is a Canadian corporation with its principal place of business in Vancouver, British Columbia, Canada. Founded in the 1950s and jointly owned and operated for decades by its U.S. parent and affiliate A.H. Lundberg Associates, Inc., LSC is a leading engineering company providing environmental systems, energy optimization, chemical handling, and process engineering services to power, resource, and processing industries. The Lundberg Defendants continue to own and share certain intellectual property, and components for the Lundberg Defendants' systems have been designed and manufactured in Canada by LSC. LSC specifically advertises flame arresters as safety components for installation in its systems to this day. LSC was owned by, was affiliated with, and/or controlled by Lundberg for years, and jointly designed and manufactured equipment and systems for Lundberg for installation in pulp and paper mills across the United States, including on information and belief in Washington State.

JURISDICTION AND VENUE

11. Subject matter jurisdiction is proper in this Court under RCW 2.08.010.

12. Venue is proper under RCW 4.12.025 because at least one of the defendants resides in King County at the time of the commencement of this action. Specifically, at least one defendant

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transacts business, has an office for the transaction of business, or transacted business at the time the cause of action arose in King County. At least one defendant did design and engineering work specially related to the systems and components of the Lundberg Defendants in King County. Moreover, at least one defendant committed a tort in King County, performed work for PCA in King County, entered into agreements with PCA in King County, or resides in King County.

13. Personal jurisdiction over Lundberg is proper in this Court because, at times relevant to this Complaint, Lundberg was a Washington entity and maintained its principal place of business in King County, Washington. Lundberg transacts business in Washington State, committed a tort in Washington State, and/or owns, uses, or possesses property situated in Washington State.

14. Personal jurisdiction over LSC is proper in this Court because LSC is a foreign entity that jointly designed, manufactured, assembled, installed, marketed, sold, and/or maintained components and systems with and for Lundberg, including products at issue in this case, in Washington State. Moreover, on information and belief, LSC was affiliated with, owned, operated, and/or controlled Lundberg at times relevant to this Complaint. LSC purposefully availed itself to the jurisdiction of this Court through systematic contacts with Washington State related to the defective products at issue in this case. Moreover, LSC has transacted business in Washington State, committed a tort in Washington State, and/or owns, uses, or possesses property situated in Washington State.

FACTUAL BACKGROUND

I. PCA HIRED LUNDBERG TO DESIGN, MANUFACTURE, ASSEMBLE, AND INSTALL SYSTEMS THAT WERE SAFE AND EFFECTIVE AT THE PCA MILLS.

15. PCA is engaged in processing raw materials to manufacture paper, containerboard, and corrugated products. PCA completes the necessary chemical processes at various mills across the country. Pertinent to this lawsuit, PCA manufactures products at mills located in Counce, Tennessee (“Counce Mill”), International Falls, Minnesota (“I’Falls Mill”), Jackson, Alabama (“Jackson Mill”), Valdosta, Georgia (“Valdosta Mill”), and Wallula, Washington (“Wallula

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Mill"). For purposes of this complaint, these mills are collectively referred to as the "PCA Mills."

16. The PCA Mills are subject to extensive regulatory oversight, including regulations pertaining to environmental standards and worker safety.

17. During the paper and pulp mill manufacturing process, combustible gases, known as non-condensable gases ("NCG"), are yielded as a byproduct. The NCGs are highly combustible and must be captured and controlled to comply with environmental regulations.

18. The Lundberg Defendants engineer, design, manufacture, assemble, market, sell, install, and maintain critical and complicated systems for the paper and pulp industry, including systems that evacuate and incinerate the NCGs ("Lundberg System").

19. The Lundberg Systems are "pollution compliance solutions" and are designed to, among other things, safely transport and remove highly combustible NCGs to effectuate compliance with environmental and worker safety standards.

20. The Lundberg Defendants advertise and hold themselves out as experts in engineering, designing, manufacturing, assembling, installing, and maintaining systems for the paper and pulp industry. For example, Lundberg states on its website, "Lundberg, an LDX Solutions brand, has 80 years of global experience engineering systems that improve operational efficiencies, expand plant capacity, and reduce pollution emissions. Our commitment to the industry and the experience of our staff give us the expertise that our clients have come to rely on." (*See* https://lundbergllc.com/). LSC states on its website, "Over the past 60 years, AHL has accumulated tremendous amount of experience servicing the pulp and paper industry. AHL has provided process engineering services and custom designed equipment to most chemical pulp and paper mill and several TMP mills in Canada and the United Stated" (sic).

21. Similar statements are also found in A.H. Lundberg Associates, Inc.'s (the predecessor company to Lundberg, LLC) marketing materials and research white papers. For example, Lundberg published working papers stating that "as the leading process system vendor for environmental compliance systems, A.H. Lundberg Associates, Inc. was instrumental in providing innovative methods for the implementations of these processes and the reduction of

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energy costs associated with their operation." (**Exhibit A**, "Environmental Projects for the Pulp and Paper Industry in the U.S.A." at 1.) Lundberg further claims that it "has played a key role in the design and supply of [combustible gas evacuation] systems to U.S. kraft pulp mills" and that its "extensive experience with [combustible gas evacuation] systems has improved [its] knowledge so that [it] may more effectively collect, condition, and transport the [gases] for incineration." (**Exhibit A** at 1–2.) Importantly, Lundberg states that "Lundberg Associates' [combustible gas evacuation] systems are designed with multiple safety features" designed to prevent an explosion from occurring in the system. (**Exhibit A** at 3.) One such safety feature is the Lundberg Flame Arresters.

22. Numerous paper and pulp mills in the United States utilize Lundberg Systems and rely on the quality and safety of the systems and their component parts to provide safe operations. They also rely on ongoing maintenance, repairs, and improvements by the Lundberg Defendants to the Lundberg Systems because the Lundberg Systems are specially designed for their specific installation and use and are proprietary rather than off-the-shelf systems. The Lundberg Systems include component parts that are designed and installed for safety purposes, and are critical in mill training, policies, and procedures such as boundaries for Process System Management, worker and safety training, and periodic maintenance.

II. THE COMBUSTIBLE NCGS MUST BE TRANSPORTED AND INCINERATED BY SPECIALLY DESIGNED LUNDBERG SYSTEMS.

23. An example of one of the Lundberg Systems is a "Non-Condensable Gas System," which removes highly combustible NCGs from the paper and pulp manufacturing processes and transports them to be destroyed in an on-site incinerator. These Lundberg Systems are subject to environmental and safety standards imposed by governmental agencies. Lundberg Systems are critical for the safe operation of paper and pulp mills, and the safety of the mill's workers. The Lundberg Defendants hold themselves out as, and are generally considered, experts in engineering, designing, manufacturing, installing, and maintaining Lundberg Systems and their component parts.

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24. In certain of the PCA Mills, PCA hired Lundberg to design, manufacture, assemble, and install Lundberg Systems that, among other things, safely processed and removed NCGs from the PCA Mills. PCA chose Lundberg to design, manufacture, assemble, and install the Lundberg Systems at the PCA Mills because, since the 1950s, the Lundberg Defendants have been the industry leader for designing and installing engineered systems, including Lundberg Systems, for use in paper and pulp mills. The Lundberg Defendants held themselves out as experts and the gold standard in the industry.

25. Although an oversimplification, the Lundberg System removes harmful and dangerous byproducts from the manufacturing processes of the pulp mill system through a series of connected pipes that ultimately lead to an incinerator. The Lundberg System is designed to remove NCGs from the mill unidirectionally, meaning that it is designed to transport all NCGs in the same direction towards the incinerator. The incinerator burns the NCGs consistent with best practices and environmental standards. The Lundberg System's intended purpose is to collect and dispose of the highly combustible NCGs while simultaneously providing a series of safeguards to prevent an explosion if a flame enters the system.

26. Lundberg has stated that "most importantly, the [Lundberg System] must incorporate safety features which will allow easy operation of the system and yet consider the fact that [NCGs are] hazardous and can cause damage to life or property if not handled properly." (**Exhibit B**, "Collection and Incineration of High Volume-Low Concentration Pulp Mill Noncondensible Gases" at 7.)

27. Lundberg recognizes that it is an industry leader in providing engineered systems for the paper and pulp industry. In fact, in recent filings, Lundberg describes itself as "a leading engineering and equipment supplier in the pulp and paper industry, wood products industry, and many other process industries."

28. Moreover, Lundberg states that it offers "spare parts, inspections, rebuilds, and product improvements for all process systems and equipment within our areas of expertise, including . . . [Lundberg Systems]." (**Exhibit C**, Lundberg Service and Spare Parts Brochure.)

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29. The Lundberg Defendants' products are ubiquitous in the paper and pulp mill industry and it is possible, if not likely, that a paper and pulp mill employee will spend an entire career working solely with Lundberg Systems.

30. Regarding Lundberg Systems, Lundberg has stated:

> Lundberg Associates has been instrumental in the design and supply of [Lundberg Systems] for U.S. mills. Various options and designs were provided in order to suit each mill's particular requirements. Potential incineration locations have included Lundberg Associates' direct fired thermal oxidizers with SO2 scrubbing, recovery boilers, power boilers, lime kilns, and open flares. Each system was individually tailored to collect the required sources and to incinerate the gases to meet government specifications within three years of implementation of the Cluster Rules.

(**Exhibit A** at 1.)

31. PCA is not an expert in designing, manufacturing, assembling, and/or installing Lundberg Systems and thus relied on Lundberg for each aspect of this process, including Lundberg's representations and warranties made about the integrity, safety, and operation of the Lundberg Systems. PCA relied on Lundberg to update the design and effectiveness of the Lundberg System over the years.

32. Lundberg knew that it was uniquely positioned to make recommendations to PCA regarding the composition of Lundberg Systems and that PCA would be relying on Lundberg's expertise in designing, manufacturing, assembling, and installing the Lundberg Systems at the PCA Mills for decades.

33. Lundberg also knew that PCA was relying on the Lundberg Defendants to design, manufacture, assemble, and install Lundberg Systems that complied with or exceeded all safety and environmental standards.

34. Lundberg similarly knew that PCA would not have hired Lundberg to design the Lundberg Systems at the PCA Mills if PCA knew that the Lundberg Systems posed undue risks to PCA's employees and/or manufacturing plants.

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III. THE LUNDBERG FLAME ARRESTERS INCORPORATED INTO THE LUNDBERG SYSTEMS ARE UNTESTED, UNCERTIFIED, AND UNSAFE.

35. The NCGs transported in the Lundberg Systems are highly flammable and a flame in the Lundberg Systems could lead to an explosion. The Lundberg Defendants specifically know this basic fact, and Lundberg acknowledged in a manual provided to PCA that "[t]he nature of the noncondensible gases is to be extremely flammable. The design of the [Lundberg System] includes multiple backup systems to insure the greatest amount of flame safeguards and to minimize any remotely possible damage." (**Exhibit D**, Operating and Maintenance Manual for the Low Volume High Concentration Non-Condensible Gas Collection and Incineration for PCA's Valdosta, Georgia Mill (J-895386) at 3.)

36. As part of the Lundberg System, the Lundberg Defendants designed, marketed, sold, installed, serviced, and maintained Lundberg Flame Arresters for PCA and other pulp and paper mills in the industry. Flame arresters are devices installed in a gas piping system, such as a Lundberg System, that are intended to prevent passage of flames through the device in the event that the gas stream is ignited.

37. Given their importance, it is typical for flame arresters to be tested and certified by an independent testing laboratory, such as Underwriters Laboratories (UL) or Factory Mutual (FM). At minimum, a flame arrester should be tested by the manufacturer against a specific standard (*e.g.*, standards set forth by the U.S. Coast Guard, American National Standards Institute, American Society of Mechanical Engineers, etc.) to ensure that it is able to perform its essential function.

38. Lundberg has marketed themselves as the leading designer, manufacturer, and installer of flame arresters in the paper and pulp mill industry with over 850 flame arresters installed throughout the industry. (*See* **Exhibits A** and **C**.)

39. On its website and to the paper and pulp industry, to this day Lundberg holds itself out as industry expert for the Lundberg Systems generally as well as the component part of Lundberg Flame Arresters specifically:

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> The collection of [Total Reduced Sulfur compounds] and volatile gases in Non-condensible Gas (NCG) and Odor Abatement Systems is an integral part of the pulp mill's environmental program. The flammability of many of these gases presents the possibility of flame propagation in the collection system's pipe lines. The flame arrester is an effective precaution against flame propagation and possible damage to process equipment. To meet the rigorous standards of our [Lundberg Systems], Lundberg developed and supplies a proprietary designed flame arrester. Since 1977, with hundreds of units installed, Lundberg's Flame Arrester has proven to be a reliable and versatile device for system safety and protection.

(*See* https://lundbergllc.com/wp-content/uploads/gravity_forms/4-b553dcb80bdfb0137377e7ec5bee4ee1/2018/09/Lundberg-Flame-Arrester.pdf?TB_iframe=true; *see also* **Exhibit E**, Lundberg Flame Arresters Brochure; **Exhibit F**, A.H. Lundberg Associates, Inc., Flame Arresters Brochure.)

40. The Lundberg Defendants knew that the Lundberg Flame Arresters were a critical component of the "multiple backup systems" and "flame safeguards" described by Lundberg. Lundberg Flame Arresters were incorporated directly into the Lundberg Systems to prevent flame propagation in the event a flame is introduced into these systems.

41. In Lundberg Systems, Lundberg Flame Arresters are integrated in strategic locations and are designed to prevent a flame from spreading from one section of the system to a second section. Flame arresters effectively serve as a firewall to ensure that a flame does not lead to a fire event in the entire system or to an explosion.

42. Flame arresters are integral to the safety of the paper and pulp mill environment because an uncontrolled fire or explosion would put employees' lives and PCA's property at risk. Simply put, without functioning flame arresters, many of the systems at a paper and pulp mill would not meet applicable standards, would not pass government inspections, and would not be safe to operate.

43. Indeed, the importance of properly functioning flame arresters is not subject to dispute. Lundberg has stated that "[i]n order to obtain the safe and reliable incineration of the NCG in any incineration point, a number of safety and operational considerations are *necessary*"

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(emphasis in original). One of these "safety and operational considerations" is the Lundberg Flame Arresters:

> Flame arresters provided in the gas lines at every LVHC NCG source and just upstream of where the NCG is injected into the incineration equipment will protect the LVHC sources and the [Lundberg System] equipment from damage in the unlikely event of a source of ignition combined with a gas combustibles concentration above the [lower flammability limit] and below the [upper flammability limit].

(**Exhibit G**, "Alternative Equipment for the Incineration of Noncondensible Gases" at 7.)

44. Lundberg has clearly stated that Lundberg Flame Arresters must be properly designed and properly functioning, or the Lundberg System is unsafe:

> Even if care is taken to keep the gases outside the explosive range, and care is taken to remove ignition sources, there is still a remote possibility that a fire may occur. To minimize any potential damage flame arresters should be installed at critical points. They are designed to prevent the spread of a fire and to minimize pipeline and equipment damage. Typically flame arresters should be placed at each LVHC NCG source and at each incineration point.

(**Exhibit H**, "Collecting and Burning Noncondensible Gases" at 6.)

45. Lundberg describes the role of Lundberg Flame Arresters in a Lundberg System as follows: "these flow through devices placed at strategic locations in the system are designed to block the propagation of the flame in the noncondensible gas system. These cylindrical devices have a core of thin gauge stainless steel to serve as the arresting method. The flame arresters are intended to:

a. Dissipate the heat of combustion as rapidly as possible by large surface area to act as a heat sink.

b. Disrupt the shock front associated with the flame propagation."

(**Exhibit D** at 3.)

46. A single Lundberg System will typically have multiple Lundberg Flame Arresters installed at various locations, and it is common for the single Lundberg System to have multiple sized Lundberg Flame Arresters incorporated. Regardless of size, the Lundberg Flame Arresters

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need to be able to prevent flame propagation or they fail their essential purpose and pose a significant safety risk to the paper and pulp mill and its employees.

47. PCA hired Lundberg to design, manufacture, assemble, install, and maintain 57 Lundberg Flame Arresters at the PCA Mills, including at mills located in Washington State.

48. Specifically, PCA hired Lundberg to design, manufacture, assemble, install, and maintain Lundberg Systems with Lundberg Flame Arresters at the following locations:

a. Counce Mill – 10 Lundberg Flame Arresters

b. I'Falls Mill – 13 Lundberg Flame Arresters

c. Jackson Mill – 2 Lundberg Flame Arresters

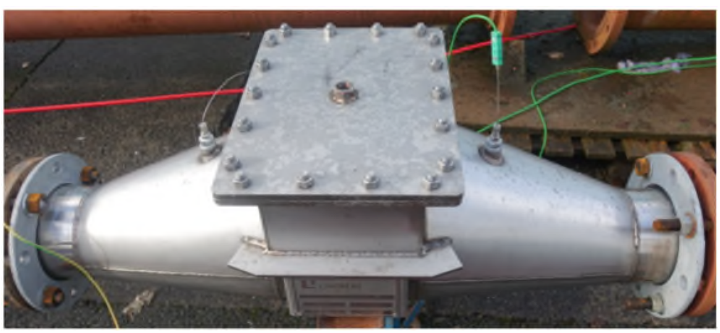
d. Valdosta Mill – 20 Lundberg Flame Arresters

e. Wallula Mill – 12 Lundberg Flame Arresters

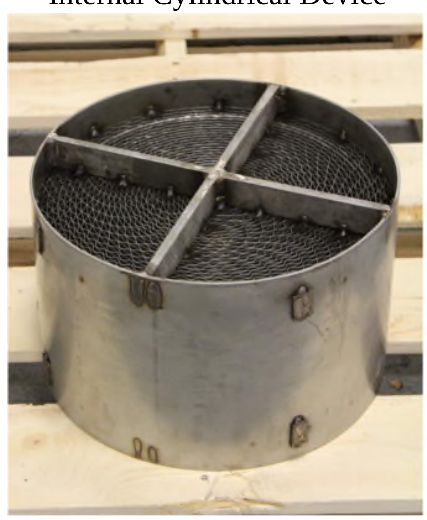
49. At the PCA Mills, the Lundberg Flame Arresters ranged from a diameter of 2" to 20", but the majority of the Lundberg Flame Arresters at the PCA Mills had diameters of 3", 4", or 6".

50. The Lundberg Flame Arresters are generally composed of two main parts: an external housing and an internal cylindrical device. Exemplary images of both the external housing and internal cylindrical device are set forth below:

External Housing



Internal Cylindrical Device



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51. The Lundberg Flame Arresters' external housing is installed directly into the Lundberg System piping. As demonstrated in the image of the external housing above, the Lundberg Flame Arresters' internal cylindrical device is not visible without removing the heavy external metal housing (the square metal piece adorned with eighteen (18) heavy bolts at the top of the above image of the external housing) and physically removing the internal cylindrical device. In order to remove the heavy metal housings and physically remove the internal cylindrical devices, all manufacturing at the mill must be stopped and the Lundberg System must be taken offline.

52. If working as designed, the NCGs pass directly through the Lundberg Flame Arrester's internal cylindrical device on their way to the incinerator. The internal cylindrical device is non-active unless and until a flame enters the Lundberg System. If a flame enters the Lundberg System, the internal cylindrical device is intended to block the propagation of flame from one section of the Lundberg System to another section of the Lundberg System.

53. Lundberg represented to PCA for decades that Lundberg Flame Arresters were well-designed safety devices, were both safe and effective, met the highest standards in the industry, and would perform their intended purpose: to stop the propagation of flames in the Lundberg Systems, meaning flames would not pass from one side of the Lundberg Flame Arresters to the other side of that critical safety device.

54. Lundberg not only designed, manufactured, sold, and installed Lundberg Flame Arresters for PCA or at PCA Mills for decades, but its staff members were onsite regularly at PCA Mills to review Lundberg Systems, provide maintenance and repairs, to replace component parts, and to update Lundberg Systems. These regular visits and work by Lundberg continued for decades until at least 2018.

55. At no point while onsite did any employee or representative of Lundberg inform PCA that the Lundberg Flame Arresters were unfit for their intended purpose due to latent defects that rendered the Lundberg Flame Arresters useless. At no point did the Lundberg Defendants make any public statements, including online, that the Lundberg Flame Arresters designed,

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manufactured, marketed, sold, and installed at pulp and paper mills across the United States and Canada were unfit for their intended purpose due to latent defects that rendered the Lundberg Flame Arresters useless. Rather, the Lundberg Defendants continued to hold themselves out as experts in designing and engineering systems for the pulp and paper industry and continued to point to the Lundberg Flame Arresters as critical safety components in their systems. These basic and material facts were concealed by the Lundberg Defendants from the pulp and paper industry and from PCA.

56. At no point while onsite did any employee or representative of Lundberg inform PCA that the Lundberg Flame Arresters were not certified, had never been tested, and did not meet U.S. and international standards. At no point did the Lundberg Defendants make any public statements, including online, that the Lundberg Flame Arresters were not tested or certified and did not meet U.S. and international standards. These basic and material facts were concealed by the Lundberg Defendants from the pulp and paper industry and from PCA.

IV. PCA LEARNS THAT THE LUNDBERG FLAME ARRESTERS CONTAIN LATENT DEFECTS THAT RENDER THEM UNFIT FOR THEIR INTENDED PURPOSE.

57. In late 2017, PCA conducted a Process Safety Management review at each of the PCA Mills. The objective of the Process Safety Management review was to, among other things, identify safety risks or hazards present at the PCA Mills.

58. PCA evaluated flammability as a potential hazard. Reviewing safety systems focused on flammability is especially important in the Lundberg Systems because, as Lundberg has stated, "[t]he nature of the noncondensible gases is to be extremely flammable." (**Exhibit D** at 3.)

59. PCA began to review and assess whether the Lundberg Flame Arresters that were incorporated into the Lundberg Systems worked properly and effectively. The review was intended to simply confirm that the Lundberg Flame Arresters worked as intended and were able to prevent passage of flames through the device in the event that the gas stream is ignited. This started with a superficial inspection of the Lundberg Flame Arresters, but soon engineers

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recommended a more detailed inspection. In many instances, this type of work would have been done, or should have been done, by Lundberg in the past years.

60. When engineers not associated with Lundberg performed a more detailed inspection, they noted that the Lundberg Flame Arresters had an atypical internal design and that internal components of the Lundberg Flame Arresters did not appear to be manufactured to appropriate tolerances (*e.g.*, the gaps were much larger than anticipated). As a result, PCA began to gather more information on the design, manufacturing, testing, and certification of the Lundberg Flame Arresters.

61. As PCA and its consultants began this information-gathering process, PCA was comforted by the fact that hundreds if not thousands of Lundberg Flame Arresters were installed in other paper and pulp mills across the country, and Lundberg generally was an expert engineering and design firm with decades of experience in the industry. PCA knew and had worked for years with Lundberg's engineers and experts and had a degree of confidence in their systems and work because Lundberg was considered an expert in the industry. PCA did not suspect, and had no reason to suspect, that the Lundberg Systems and Lundberg Flame Arresters were far from what was represented, marketed, and sold to PCA.

62. Out of an abundance of caution, however, PCA requested that Lundberg provide design and manufacturing specifications as well as all certifications for the Lundberg Flame Arresters. PCA also requested that Lundberg provide information demonstrating that the Lundberg Defendants tested the Flame Arresters to accepted U.S. and international standards before placing them on the market for the stated purpose of mitigating the risk of a flame spreading through a Lundberg System.

63. Lundberg delayed responding initially, and ongoing projects by Lundberg at PCA Mills were jeopardized because of a perceived refusal by Lundberg to provide basic information. Finally, for the first time ever, Lundberg stated that they could not provide such information because they in fact <u>had never tested or certified the Lundberg Flame Arresters to any applicable standards</u>, either internally or externally with a third-party testing facility. Lundberg also refused

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to provide any actual design and manufacturing specifications, and only provided a rough, hand-drawn schematic and a 1985 article that set forth general engineering techniques for flame arresters.

64. Lundberg was ultimately either unable or unwilling to provide any data or information showing that the Lundberg Flame Arresters were able to perform their intended purpose. Lundberg thus had no factual basis to state that the Lundberg Flame Arresters are "an effective precaution against flame propagation and possible damage to process equipment," and Lundberg further knew that without any testing or certification that the statement was false.

65. Lundberg also knew that it had no basis to state that Lundberg Flame Arresters have "proven to be a reliable and versatile device for system safety and protection." (**Exhibits E** and **F**.) That statement is demonstrably false.

66. PCA and many others in the industry relied on the Lundberg Defendants' representations, statements, and warranties when evaluating and making the decision on what engineering firm to hire, what systems to install, and what flame arresters to use in those systems. For decades, the Lundberg Defendants concealed these basic facts—no testing, no certifications and no effort to prove the design of a critical safety device—from PCA and the industry.

67. Simply put, this was the first time PCA learned that the Lundberg Defendants, as experts in the industry, had never tested or certified the Lundberg Flame Arresters to applicable U.S. and international standards, including applicable ISO and U.S. Coast Guard protocols and/or standards.

68. PCA relied on the Lundberg Defendants' engineering expertise, specific to the paper and pulp mill industry, and several express representations regarding both the efficacy and safety of the Lundberg Systems and the Lundberg Flame Arresters, when evaluating and deciding to hire Lundberg to design, install, maintain, and update systems. PCA relied on these same things when deciding to purchase component parts from Lundberg such as new or replacement Lundberg Flame Arresters, including as recently as November 2017. If PCA had known that the Lundberg Defendants had never tested and certified the Lundberg Flame Arresters to applicable standards,

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it never would have purchased and installed the Lundberg Systems.

V. PCA Hired an Independent Third-Party Certification Facility to Test the Lundberg Flame Arresters. The Testing Demonstrated Conclusively That the Lundberg Flame Arresters Had Latent Defects and Were Unable to Perform Their Intended Purpose.

A. A Test Lundberg Flame Arrester Failed Independent Third-Party Testing.

69. In an effort to determine whether the Lundberg Flame Arresters were an effective safety device, which was required due to their never being tested and certified by the Lundberg Defendants, PCA hired an independent engineering consulting firm and an independent third-party testing facility, Aber Shock in Wales, United Kingdom, to test the efficacy of a Lundberg Flame Arrester.

70. Aber Shock is one of the only flame arrester testing and certification facilities in the world. Aber Shock was available to test one Lundberg Flame Arrester in January 2018 ("2018 Test").

71. PCA already had purchased a brand new 6" Lundberg Flame Arrester directly from Lundberg in November 2017 ("6" Test Flame Arrester").

72. The 6" Test Flame Arrester had never been introduced into a Lundberg System and was brand new at the time of the 2018 Test. Put differently, the 6" Test Flame Arrester was exactly as the Lundberg Defendants had designed, manufactured and sold the product, with no changes or use, and when tested was in the same condition as it was when it was purchased by PCA from Lundberg.

73. The 6" Test Flame Arrester was manufactured by Lundberg in 2017 and was assigned P.O. No. 227024, Project No. J-175728, and Equipment No. 175728-G801-01:

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74. Aber Shock's inspection showed that the 6" Test Flame Arrester had more internal space than anticipated—*i.e.*, an unanticipated gap between the external housing and the internal cylindrical device. Aber Shock's inspection also found that there was a larger than anticipated gap around the 6" Test Flame Arrester's internal cylindrical device that could allow gases and a flame to bypass the internal cylindrical device that was in place to provide the heat sink. The internal cylindrical device also had larger openings than competitors' designs.

75. Aber Shock conducted industry approved testing to determine whether the 6" Test Flame Arrester performed its intended purpose of preventing the proliferation of a flame introduced into a Lundberg System.

76. In accordance with established testing protocol for flame arresters (ISO 16852 section 7.3.2.2), Aber Shock intended to conduct the 2018 Test by subjecting the 6" Test Flame Arrester to a series of tests with each test increasing in intensity.

77. Under this testing protocol, the first test would subject the 6" Test Flame Arrester to the least amount of energy (*e.g.*, the lowest concentration of flammable gas). If the 6" Test Flame Arrester performed as intended, subsequent tests would gradually increase the energy to determine whether the 6" Test Flame Arrester was suitable for the Lundberg Systems: the purpose for which it had been designed, manufactured, and sold to PCA by Lundberg.

78. The independent third-party test that was conducted in accordance with an international testing protocol quickly demonstrated that the 6" Test Flame Arrester was completely ineffective. Indeed, during the first, lowest energy test, a flame easily passed through the 6" Test Flame Arrester.

79. Despite Aber Shock anticipating several rounds of testing, only one test was able to be performed due to the impact that the lowest energy test had on the internal cylindrical device of the 6" Test Flame Arrester. The image below marked (b) shows the damage to the unprotected face of the 6" Test Flame Arrester's internal cylindrical device immediately after the 2018 Test:

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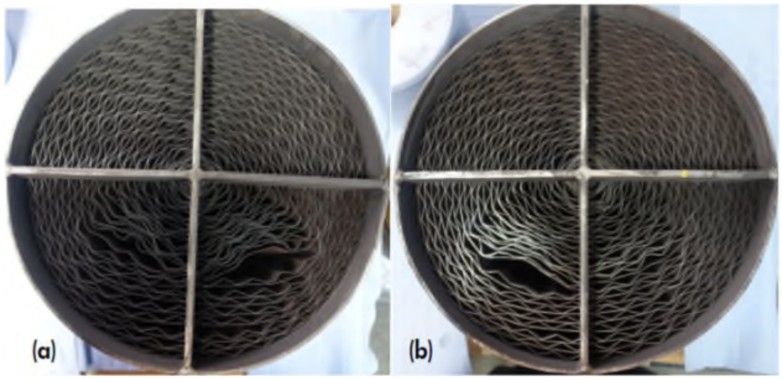

80. This failure is exactly contrary to the stated purpose of incorporating the Lundberg Flame Arresters in the Lundberg Systems and presents a risk of explosion, injury, and death to anyone working near the Lundberg Systems.

81. Luckily, the PCA Mills never experienced an explosion caused by the Lundberg Flame Arresters. Therefore, it was not until consultants for PCA tested the 6" Test Flame Arrester—in January 2018—that PCA had an opportunity to learn that the Lundberg Flame Arresters were possibly defective and unlikely to prevent the propagation of flames.

82. As confirmed during the 2018 Test at Aber Shock, the 6" Test Flame Arrester failed to provide any protection against flame propagation, failed to serve as a flame arrester, failed to perform as a safety device, and failed to serve the basic purpose for which it was designed, manufactured, purchased, and installed. Instead, it accelerated propagation of the flame through the system, which is directly contrary to the intended purpose of the flame arrester.

83. After the independent test results were known, PCA worked diligently to evaluate replacement flame arresters manufactured and produced by other companies, hired a new engineering and design firm to provide effective workarounds and changes in existing systems, and removed all Lundberg Flame Arresters from the PCA Mills.

84. Each of the 57 Lundberg Flame Arresters that had been installed at the PCA Mills were promptly disassembled and removed from the PCA Mills because they had not been designed, manufactured, tested, or certified to U.S. and international standards, simple facts that had been concealed from PCA by Lundberg for decades. And, as a result of the 2018 Test, the Lundberg Flame Arresters also appeared to have latent, internal defects and an inability to

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eliminate flame propagation in the Lundberg Systems. PCA did all of this at its own costs, and also took steps to suspend or terminate virtually all work being done at its mills by Lundberg.

85. The process of removing all Lundberg Flame Arresters required the PCA Mills to be intermittently shut down, required new parts to be acquired, and required significant labor costs and time.

86. PCA replaced the Lundberg Flame Arresters with a certified and tested flame arrester designed and manufactured by a non-party.

87. PCA took these steps because the defective, untested, and uncertified Lundberg Flame Arresters posed serious risk to PCA's property and employees and had to be removed and replaced.

B. The 2019 Test Confirmed That Lundberg Flame Arresters Are Defective.

88. After removing the Lundberg Flame Arresters from the PCA Mills, PCA sent multiple Lundberg Flame Arresters to Aber Shock, the same independent third-party testing facility that conducted the 2018 Test. PCA wanted to validate the 2018 Test, and to test multiple Lundberg Flame Arresters of various sizes that had been in service.

89. Aber Shock conducted this testing in September 2019 ("2019 Test").

90. Aber Shock conducted the tests in accordance with U.S. Coast Guard testing protocols and standards, under the supervision of PCA and engineers from outside PCA.

91. During the 2019 Test, Lundberg Flame Arresters that were 2", 4", and 6" capacity were tested and <u>each and every Lundberg Flame Arrester failed each test</u>. The Lundberg Flame Arresters did absolutely nothing to stop or slow the passage of a flame from one side to another, and flame easily and quickly passed through the internal cylindrical device.

92. Remarkably, the Lundberg Flame Arresters actually <u>increased</u> the velocity and magnitude of flame propagation.

93. The 2019 Test showed that <u>it is more dangerous to install a Lundberg Flame Arrester in a Lundberg System than it is to simply install a straight pipe of the same size</u>. In other words, Lundberg Flame Arresters act as flame accelerators, not flame arresters, and are the exact

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opposite in performance and efficacy from a safety device. The results of the testing are stark and demonstrate the unreasonably dangerous nature of the Lundberg Flame Arresters.

94. PCA spent millions of dollars to purchase the Lundberg Systems, to test the Lundberg Flame Arresters that were defective as designed, manufactured, sold, and installed by the Lundberg, to purchase replacements for the defective Lundberg Flame Arresters, and to stop manufacturing to complete the labor needed to install the new certified flame arresters in the Lundberg Systems. All of these costs were brought about by the safety risks posed by the defective Lundberg Systems and concealed by Lundberg. PCA seeks to recover all these costs and fees.

95. PCA reasonably believed that the Lundberg Defendants had designed, manufactured, tested and/or certified the Lundberg Flame Arresters to U.S. and international standards prior to installing them—taking reasonable steps to ensure that the Lundberg Flame Arresters actually worked. Lundberg concealed these material facts from PCA and the industry. If PCA knew that the Lundberg Defendants had never tested and certified the Lundberg Flame Arresters, PCA would not have purchased the Lundberg System from Lundberg.

96. PCA now seeks to recover all costs associated with the Lundberg Defendants' defective products, including the Lundberg Systems and Lundberg Flame Arresters.

97. To the extent any applicable statute of limitation is at issue, it should be tolled due to PCA's inability to discover the latent defects and Lundberg's purposeful and fraudulent concealment of both the latent defects and material facts. It would be inequitable to bar PCA from proceeding with this claim given the bad acts of the Lundberg Defendants and the difficulty inherent in discovering and confirming that the Lundberg Flame Arresters are defectively designed, defectively manufactured, unsafe, and unfit for use as expressly and implicitly warranted. This is especially true because the Lundberg Defendants held themselves out as experts—basically the gold standard—in the industry for decades.

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FIRST CAUSE OF ACTION
PRODUCT LIABILITY – NEGLIGENCE

98. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

99. PCA was harmed by the negligence of the Lundberg Defendants in that the Lundberg Systems and Lundberg Flame Arresters were not reasonably safe as designed.

100. PCA was harmed by the negligence of the Lundberg Defendants in that the Lundberg Systems and Lundberg Flame Arresters were not reasonably safe because adequate warnings or instructions were not provided.

101. The Lundberg Systems and Lundberg Flame Arresters are not reasonably safe as designed because, at the time of manufacture, the likelihood that the Lundberg Systems and Lundberg Flame Arresters would cause PCA harm and the seriousness of the harms facing PCA outweighed the burden on the Lundberg Defendants to design a product that would have prevented those harms.

102. At the time of manufacture, an alternative design was practical, feasible, and already in existence and such alternative design would not encumber the purpose of the Lundberg Systems and Lundberg Flame Arresters. Indeed, best practices for designing and manufacturing NCG evacuation systems (like the Lundberg System) and flame arresters (like the Lundberg Flame Arresters) demonstrate that the Lundberg Defendants' proprietary design is unreasonably unsafe and defective.

103. Moreover, the Lundberg Systems and Lundberg Flame Arresters are not reasonably safe because adequate warnings were not provided at the time of manufacture. Namely, the Lundberg Defendants did not provide warnings informing PCA that the Lundberg Systems and Lundberg Flame Arresters were ineffective, untested, unsafe, uncertified, and unable to perform their intended purpose.

104. Additionally, the Lundberg Systems and Lundberg Flame Arresters are not reasonably safe because the Lundberg Defendants learned after manufacturing the Lundberg

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Systems and Lundberg Flame Arresters, or should have learned after manufacturing the Lundberg Systems and Lundberg Flame Arresters, that the Lundberg Systems and Lundberg Flame Arresters were inherently dangerous and not suitable for installation and use in the PCA Mills.

105. The Lundberg Defendants had a duty to warn PCA about the danger posed by the Lundberg Systems and Lundberg Flame Arresters at the time of manufacture, or, alternatively, subsequent to manufacture.

106. The Lundberg Defendants failed to provide a warning or instruction to PCA regarding the inherently dangerous and defective nature of the Lundberg Systems and Lundberg Flame Arresters.

107. As demonstrated above, the Lundberg Systems and Lundberg Flame Arresters are inherently and unreasonably unsafe and fail to perform their intended purpose.

108. The inherently unsafe nature of the Lundberg Systems and Lundberg Flame Arresters was known, or should have been known, to the Lundberg Defendants before or after the date of manufacture.

109. The Lundberg Defendants should have tested the Lundberg Flame Arresters before installing them in the Lundberg Systems.

110. The Lundberg Defendants should have certified the Lundberg Flame Arresters before installing them in the Lundberg Systems.

111. The Lundberg Defendants' failure to test the Lundberg Flame Arresters is unreasonable, unsafe, unjustified, and not consistent with engineering duties or best practices.

112. The Lundberg Defendants' failure to certify the Lundberg Flame Arresters is unreasonable, unsafe, unjustified, and not consistent with engineering duties or best practices.

113. The Lundberg Defendants also should have followed engineering best practices when designing the Lundberg Flame Arresters to ensure that the Lundberg Flame Arresters did not suffer from the aforementioned inherent and latent problems.

114. Nevertheless, the Lundberg Defendants were negligent in designing and/or failing to warn of the risks of the Lundberg Flame Arresters in violation of law.

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115. The Lundberg Defendants had a duty to act as a reasonable engineering firm when designing, manufacturing, assembling, installing, marketing, selling, and maintaining the Lundberg Systems and the Lundberg Flame Arresters.

116. The Lundberg Defendants breached this duty to PCA by failing to test the Lundberg Flame Arresters and accordingly failing to recognize and/or disclose that the Lundberg Flame Arresters were incapable of performing their stated purpose.

117. PCA justifiably relied on the Lundberg Defendants' representations, both express and implied, as well as its stated expertise in the field of engineering for the paper and pulp industry.

118. PCA was directly and proximately damaged due to the Lundberg Defendants' negligent conduct in an amount to be determined at trial.

SECOND CAUSE OF ACTION
PRODUCT LIABILITY – STRICT LIABILITY

119. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

120. The Lundberg Defendants are strictly liable to PCA because PCA's harm was caused by the fact that the Lundberg Systems and Lundberg Flame Arresters were not reasonably safe in construction and did not conform to Lundberg's express warranty regarding the Lundberg Systems and Lundberg Flame Arresters.

121. The Lundberg Systems and Lundberg Flame Arresters are not safe in construction because when they left the control of the Lundberg Defendants, the Lundberg Systems and Lundberg Flame Arresters deviated in some material way from the design specifications or performance standards of the Lundberg Defendants.

122. Specifically, despite Lundberg's statements to the contrary, the Lundberg Systems and Lundberg Flame Arresters were unsafe and not fit for installation or use in the PCA Mills, including because the Lundberg Flame Arresters were not effective in acting as a safeguard to prevent flames from spreading in the Lundberg Systems.

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123. Similarly, the Lundberg Flame Arresters were not consistent with the performance standards of the Lundberg Defendants, which, at minimum, required the Lundberg Flame Arresters to prevent the spread of flames in the Lundberg System and act as a "flame safeguard" in the Lundberg Systems.

124. Moreover, the Lundberg System and Lundberg Flame Arresters did not conform to Lundberg's express warranty regarding the Lundberg System and Lundberg Flame Arresters.

125. Specifically, Lundberg stated that the Lundberg Flame Arresters are "an effective precaution against flame propagation and possible damage to process equipment."

126. Lundberg also stated that the Lundberg Flame Arresters have "proven to be a reliable and versatile device for system safety and protection."

127. Lundberg also stated that the Lundberg Flame Arresters were developed in a proprietary manner to "meet the rigorous standards of" Lundberg Systems.

128. Each of these statements were material to PCA and justifiably relied upon by PCA.

129. Each of these statements were materially false and Lundberg knew, or should have known, that these statements were false. Specifically, among other reasons, the Lundberg should have known that the statements were false due to their failure to test or certify the Lundberg Flame Arresters, a key safety feature of the Lundberg Systems.

130. Lundberg made these materially false statements with the intention of inducing reliance on the part of PCA so that PCA would opt to purchase the Lundberg System and Lundberg Flame Arrester as opposed to a competitor's product.

131. PCA would not have purchased or utilized the Lundberg System or Lundberg Flame Arresters if PCA knew that the safeguards inherent in the Lundberg Systems and Lundberg Flame Arresters were defective.

132. PCA was harmed by the Lundberg Defendants' conduct—conduct for which the Lundberg Defendants are strictly liable—in an amount to be determined at trial.

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THIRD CAUSE OF ACTION
NEGLIGENCE

133. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

134. The Lundberg Defendants are expert engineering firms that contract to design, manufacture, assemble, and install systems, including Lundberg Systems and Lundberg Flame Arresters, at paper and pulp mills.

135. As such, the Lundberg Defendants had a duty to design its systems, including the Lundberg Systems and Lundberg Flame Arresters, with appropriate safeguards sufficient to minimize the risk encountered in transporting and incinerating combustible NCGs.

136. One aspect of this duty was the Lundberg Defendants' duty to test the Lundberg Systems and Lundberg Flame Arresters prior to representing that they were safe and appropriate for installation and use in the PCA Mills, including Lundberg's representation that the Lundberg Flame Arresters were an effective safeguard to prevent flame propagation in Lundberg Systems.

137. The Lundberg Defendants' duties were especially important in this context given that Lundberg knew that PCA was relying on it to design and install a safe and compliant Lundberg System in the PCA Mills and that failure to provide a safe and compliant Lundberg System put employees' lives and PCA's property at risk.

138. To address the known risk of combustion in Lundberg Systems, the Lundberg Defendants used a "proprietary design" to manufacture the Lundberg Flame Arresters, specifically noting that the Lundberg Flame Arresters were developed in a proprietary manner to "meet the rigorous standards of [Lundberg Systems]." At a minimum, the "rigorous standards of [Lundberg Systems]" includes safe operation as advertised and marketed by Lundberg.

139. Nevertheless, the Lundberg Defendants breached their duty to PCA by designing, manufacturing, assembling, and installing defective Lundberg Systems with defective Lundberg Flame Arresters.

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140. Both the Lundberg Systems and the Lundberg Flame Arresters had latent defects that could not be and should not have reasonably been discovered by PCA until third-party testing demonstrated and confirmed that the Lundberg Systems and Lundberg Flame Arresters were defective. This did not occur until September 2019.

141. Further, Lundberg breached its duty to PCA by installing Lundberg Flame Arresters that had never been tested, had not been certified, and for which the efficacy had not been confirmed.

142. The Lundberg Defendants' breach is especially egregious given that the Lundberg Flame Arresters are a last line of defense in the Lundberg System and are supposed to prevent property damage and serious injury or death.

143. The Lundberg Defendants' unsafe and negligent attitude towards the safety of the Lundberg System, including its failure to test the Lundberg Flame Arrester, is the direct and proximate cause of PCA's injury.

144. Indeed, PCA would not have spent millions of dollars testing and ultimately replacing the Lundberg Systems and Lundberg Flame Arresters had these safety products worked as advertised and marketed.

145. PCA also would not have purchased, installed, or maintained the Lundberg Systems or Lundberg Flame Arresters if it had known that these products contained latent defects.

146. PCA also would not have replaced the defective Lundberg Systems and Lundberg Flame Arresters had they not been defective.

147. PCA could have avoided shutting down the PCA Mills to complete the repair and replacement work had the Lundberg Systems and Lundberg Flame Arresters performed as warranted, advertised, and marketed by Lundberg.

148. PCA was harmed by the Lundberg Defendants' negligence in the amount of millions of dollars, the exact amount to be determined at trial.

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FOURTH CAUSE OF ACTION

BREACH OF IMPLIED WARRANTY – FITNESS FOR A PARTICULAR PURPOSE

149. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

150. Lundberg knew that PCA hired it to design a safe and effective Lundberg System at the PCA Mills.

151. Lundberg also knew that PCA was not an expert in the design, manufacture, assembly, or installation of Lundberg Systems.

152. Lundberg knew that PCA was relying on the Lundberg Defendants' engineering expertise for paper and pulp mills when PCA hired Lundberg to design, manufacture, assemble, and install the Lundberg System and Lundberg Flame Arresters.

153. By virtue of Lundberg stating that the Lundberg Systems and Lundberg Flame Arresters were safe and fit for installation and use in the PCA Mills, including Lundberg's representation that the Lundberg Flame Arresters were an effective safeguard against flame propagation, PCA justifiable and reasonably believed that Lundberg had a basis to represent that the Lundberg Flame Arresters would prevent flame propagation throughout the Lundberg System.

154. By virtue of Lundberg installing the Lundberg Flame Arresters in the Lundberg System after having repeatedly noted the highly combustible nature of NCG gases, PCA justifiably and reasonably believed that the Lundberg Flame Arresters were safe and fit to be installed and used in the Lundberg Systems.

155. At minimum, PCA justifiably and reasonably believed that the Lundberg Defendants had tested the Lundberg Flame Arresters prior to integrating them as a safeguard in the highly combustible Lundberg System given how many representations Lundberg made regarding the need for Lundberg Systems to incorporate properly operating flame arresters.

156. Nevertheless, the Lundberg Defendants had not tested the Lundberg Flame Arresters, and Lundberg and had no basis to represent that the Lundberg System was safe for use in the PCA Mills.

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157. Had the Lundberg Defendants tested the Lundberg Flame Arresters, they would have quickly discovered that the proprietary design utilized by the Lundberg Defendants was ineffective and actually served to act as a flame accelerator as opposed to a flame arrester.

158. As a result of the Lundberg Defendants' unreasonable decision not to test the Lundberg Flame Arresters, the Lundberg Systems and the Lundberg Flame Arresters were not fit for their intended purpose of safely transporting and disposing of NCGs at the PCA Mills.

159. Lundberg knew that PCA was relying on the Lundberg Defendants' status as an expert engineering firm when they manufactured, designed, assembled, and installed the defective Lundberg Flame Arresters in the Lundberg Systems.

160. PCA is not an expert engineering firm and does not design, manufacture, assemble, or install Lundberg Systems. It thus justifiably and reasonably relied on the Lundberg Defendants' expertise and design specifications.

161. PCA had no way of knowing that the Lundberg Flame Arresters were defectively designed until the 2019 Tests were completed.

162. Lundberg's breach of the implied warranties directly and proximately caused PCA's injury in an exact amount to be determined at trial.

FIFTH CAUSE OF ACTION
BREACH OF EXPRESS WARRANTY

163. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

164. Lundberg expressly warranted that the Lundberg Flame Arresters are "an effective precaution against flame propagation and possible damage to process equipment."

165. Lundberg also stated that the Lundberg Flame Arresters have "proven to be a reliable and versatile device for system safety and protection."

166. Lundberg also stated that the Lundberg Flame Arresters were developed in a proprietary manner to "meet the rigorous standards of" Lundberg Systems.

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167. These statements were material to PCA and PCA justifiably relied on these statements made by Lundberg.

168. PCA would not have hired Lundberg to design, manufacture, assemble, and install the Lundberg Systems and Lundberg Flame Arresters at the PCA Mills but for the representations that the Lundberg Systems and Lundberg Flame Arresters were safe and compliant with all applicable environmental and safety regulations and standards.

169. These statements made by Lundberg are false as shown by the results of the 2019 Tests.

170. Moreover, Lundberg had no basis on which to make these statements as they had unreasonably and unjustifiably decided to not test or certify the Lundberg Flame Arresters.

171. Lundberg made express safety-related statements for which it had no basis in order to induce PCA to purchase and install the Lundberg Systems and Lundberg Flame Arresters at the PCA Mills.

172. PCA's justifiable reliance led it to expose its employees and mills to unrealized danger. It also exposed PCA to millions of dollars in damages, none of which would have occurred but for the unreasonable and unjustifiable misrepresentations made by Lundberg.

173. Lundberg breached express warranties made to PCA.

174. Lundberg's breach of the express warranties directly and proximately caused PCA's injury in an exact amount to be determined at trial.

SIXTH CAUSE OF ACTION

FRAUD

175. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

176. Lundberg knew that the Lundberg Systems transport flammable and highly combustible NCGs and that "these gases present the possibility of flame propagation in the collection system's pipelines."

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177. The Lundberg Flame Arresters were designed and marketed as a safeguard to minimize the risk of flame propagation in the Lundberg Systems.

178. Nevertheless, the Lundberg Defendants never tested the efficacy of the Lundberg Flame Arresters, never had them certified, and had no basis on which to believe that they would act as a safeguard to prevent flame propagation.

179. Lundberg thus made false statements of material fact regarding the efficacy of the Lundberg Flame Arresters. Moreover, Lundberg actively concealed material facts—no testing and no certification—from PCA.

180. Specifically, Lundberg stated that the Lundberg Flame Arresters are "an effective precaution against flame propagation and possible damage to process equipment."

181. Lundberg also stated that the Lundberg Flame Arresters have "proven to be a reliable and versatile device for system safety and protection."

182. Lundberg also stated that the Lundberg Flame Arresters were developed in a proprietary manner to "meet the rigorous standards of" Lundberg Systems.

183. Lundberg knew that these statements of material fact were false because they never tested or certified the Lundberg Flame Arresters and thus had no basis on which to make such claims.

184. Lundberg made these statements to induce PCA to buy Lundberg Systems and Lundberg Flame Arresters in an effort to make a profit and notwithstanding that it put PCA's employees at risk of serious injury or death and threatened property damage to PCA's Mills.

185. Lundberg knew that PCA was relying on the Lundberg Defendants' engineering expertise and that PCA relied on these and other representations when deciding to hire Lundberg to design, manufacture, install, and assemble the Lundberg Systems and Lundberg Flame Arresters at the PCA Mills.

186. Lundberg also knew that PCA would not have hired Lundberg to design, manufacture, install, and assemble the Lundberg Systems and Lundberg Flame Arresters if PCA knew that the Lundberg Flame Arresters were ineffective and did not prevent flame propagation.

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187. PCA was directly and proximately damaged by Lundberg's material and knowing false statements because it cost PCA millions of dollars to purchase the Lundberg Systems, maintain the Lundberg Systems, test the Lundberg Flame Arresters, replace the Lundberg Flame Arresters with work-arounds to incorporate a non-native product into the Lundberg System, and stop production at the PCA Mills to complete the replacement.

188. PCA's injury was directly and proximately caused by the knowingly false statements of Lundberg.

189. Lundberg's fraudulent conduct and fraudulent statements directly and proximately caused PCA's injury in an exact amount to be determined at trial.

SEVENTH CAUSE OF ACTION

UNFAIR AND DECEPTIVE BUSINESS PRACTICES (RCW 19.86.020)

190. PCA realleges and incorporates all prior paragraphs of this Complaint as if fully set forth herein.

191. Pursuant to RCW 19.86.020, Lundberg engaged in unfair methods of competition and unfair or deceptive acts or practices in the conduct of knowingly selling PCA the defective Lundberg Systems and Lundberg Flame Arresters with latent defects.

192. Lundberg held itself out to be an expert engineering firm with a specific emphasis in the paper and pulp mill industry.

193. In fact, Lundberg describes itself as "a leading engineering and equipment supplier in the pulp and paper industry, wood products industry, and many other process industries."

194. Lundberg acknowledges that "[t]he nature of the noncondensible gases is to be extremely flammable. The design of the [Lundberg System] includes multiple backup systems to insure the greatest amount of flame safeguards and to minimize any remotely possible damage."

195. The "backup systems" and "flame safeguards" described by Lundberg include, among other things, the Lundberg Flame Arresters.

196. Lundberg describes the role of Lundberg Flame Arresters in a Lundberg System as follows: "these flow through devices placed at strategic locations in the system are designed to

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block the propagation of the flame in the noncondensible gas system. These cylindrical devices have a core of thin gauge stainless steel to serve as the arresting method. The flame arresters are intended to:

a. Dissipate the heat of combustion as rapidly as possible by large surface area to act as a heat sink.

b. Disrupt the shock front associated with the flame propagation."

197. The Lundberg Flame Arresters are an integral part of the Lundberg System and without properly functioning Lundberg Flame Arresters the Lundberg System would be unsafe and not fit for installation in a paper and pulp mill.

198. In fact, in marketing material prepared and disseminated by Lundberg, Lundberg describes the Flame Arresters as follows:

> The collection of [Total Reduced Sulfur compounds] and volatile gases in Noncondensible [sic] Gas (NCG) and Odor Abatement Systems is an integral part of the pulp mill's environmental program. The flammability of many of these gases presents the possibility of flame propagation in the collection system's pipe lines. The flame arrester is an effective precaution against flame propagation and possible damage to process equipment. To meet the rigorous standards of our Lundberg Systems, Lundberg Associates developed and supplies a proprietary designed flame arrester.
>
> Since 1977, in more than two hundred installations, the Lundberg Associates' Flame Arrester has proven to be a reliable and versatile device for system safety and protection.

199. Nevertheless, Lundberg—an expert engineering firm in the paper and pulp mill industry—failed to test the Lundberg Flame Arresters despite acknowledging that the Lundberg Flame Arresters are an integral safeguard for the Lundberg Systems.

200. Had the Lundberg Defendants tested the Lundberg Flame Arresters, they would have known that the Lundberg Flame Arresters do not work and, instead, accelerate flames throughout the Lundberg Systems.

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201. Lundberg's false representations regarding the safety and efficacy of the Lundberg Systems and the Lundberg Flame Arresters constitute a deceptive and unfair business practice.

202. Lundberg's reliance on its status as an expert engineering firm to sell Lundberg Systems without testing the integral safeguards, such as the Lundberg Flame Arresters, is a deceptive and unfair business practice.

203. PCA would not have purchased the Lundberg System or Lundberg Flame Arrester if Lundberg had disclosed that it had not tested the Lundberg Flame Arresters or that the Lundberg System was unsafe and unfit for installation and use in the PCA Mills.

204. PCA would not have purchased the Lundberg System or Lundberg Flame Arresters if Lundberg had disclosed that the Lundberg System was unsafe and lacking effective safeguards.

205. PCA would not have purchased the Lundberg System if Lundberg had disclosed that the Lundberg Flame Arresters were not fit for their stated purpose of mitigating the spread of flames throughout the Lundberg System.

206. PCA was harmed by Lundberg's deceptive and unfair business practices in an amount to be determined at trial. Moreover, pursuant to RCW 19.86.090, PCA seeks treble damages and attorneys' fees for Lundberg's unfair and deceptive business practices.

PRAYER FOR RELIEF

WHEREFORE, PCA requests the following relief:

A. All damages associated with purchasing and maintaining the defective Lundberg Systems and Lundberg Flame Arresters, the exact amount to be determined at trial;

B. All damages associated with testing the defective Lundberg Systems and Lundberg Flame Arresters, the exact amount to be determined at trial;

C. All damages associated with replacing the defective Lundberg Flame Arresters, the exact amount to be determined at trial;

D. All damages associated with Lundberg's fraudulent statements and fraudulent concealment of the defective nature of the Lundberg Systems and Lundberg Flame Arresters;

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E. All damages associated with Lundberg's unfair and deceptive business practices, including treble damages pursuant to RCW 19.86.090;

F. All attorneys' fees, court costs, and other associated expenses; and

G. All other damages deemed suitable by this Court.

Respectfully submitted this 12th day of August, 2020.

/s/ J. Andrew Howard
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EXHIBIT A

Environmental Projects for the Pulp and Paper Industry in the U.S.A.

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SUMMARY

U.S. pulp and paper mills have been actively upgrading their environmental systems in order to comply with new government regulations restricting emissions. These include noncondensible gas collection and incineration systems, as well as foul condensate treatment systems. A. H. Lundberg Associates, Inc. has played a key role in implementing these projects. Innovative techniques and processes for minimizing capital and operating costs have been developed. Such technology includes thermal oxidation of noncondensible gases in the recovery boiler, reduction in the quantity of collected dilute noncondensible gases, and efficient heat recovery in steam stripping systems. Methods for reducing natural gas usage in dedicated incinerators as well as waste heat boilers for heat recovery have also been implemented. The technology applied in U.S. projects can be utilized as well in Chile.

INTRODUCTION

The United States Environmental Protection Agency (EPA) promulgated their MACT I and MACT III Cluster Rule regulations in April of 1998 requiring the reduction of Hazardous Air Pollutants (HAPs) in both air and water emissions. As the leading process system vendor for environmental compliance systems, A. H. Lundberg Associates, Inc. was instrumental in providing innovative methods for the implementation of these processes and the reduction of energy costs associated with their operation. Similar process strategies may be applicable for implementation in Chile.

This paper presents an overview of several of the process systems installed to implement the regulations in a cost effective manner. Included are discussions of evaporator integrated condensate stripping systems, waste heat boilers on direct fired thermal oxidizers, methods for reduction in the volume of dilute gas collection flow, and thermal oxidation of dilute noncondensible gas in recovery boilers.

LOW VOLUME HIGH CONCENTRATION NCG

The MACT I Cluster Rules regulations required collection and disposal of low volume high concentration noncondensible gases (LVHC NCG) for all kraft pulp mills to be completed by April of 2001. LVHC NCG is defined by its concentration as being above the upper explosion limit. It contains TRS (Total Reduced Sulfur) compounds, including hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide, as well as VOC (Volatile Organic Compounds), particularly turpentine and methanol. Sources of LVHC NCG include turpentine recovery vents, blow heat recovery vents, evaporator sources, and continuous digester relief.

Lundberg Associates has been instrumental in the design and supply of LVHC NCG systems for U.S. mills. Various options and designs were provided in order to suit each mill's particular requirements. Potential incineration locations have included Lundberg Associates' direct fired thermal oxidizers with SO_2 scrubbing, recovery boilers, power boilers, lime kilns, and open flares. Each system was individually tailored to collect the required sources and to incinerate the gases to meet government specifications within three years of implementation of the Cluster Rules.

HIGH VOLUME LOW CONCENTRATION NCG

The compliance date for U.S. mills to collect and dispose of the high volume low concentration (HVLC NCG) is still more than four years away. However, many mills are actively pursuing their options for HVLC NCG systems in order to avoid a last minute rush to meet compliance. Even prior to implementation of the Cluster Rules, Lundberg Associates has played a key role in the design and supply of HVLC NCG systems to U.S. kraft pulp mills. Extensive experience with NCG systems has improved our knowledge so that we may more effectively collect, condition, and transport the HVLC NCG for incineration. Typical HVLC NCG sources include brown stock washer hoods, brown stock washer filtrate tanks, weak and strong black liquor storage tanks, soap skimming tanks, and knotter hoods. Also, washers, filtrate tanks, and blow tanks in oxygen delignification systems are collected as HVLC NCG sources. The potential incineration locations for HVLC NCG are the same as described above for LVHC NCG. Oftentimes, however, the large volume of HVLC NCG limits the possible incineration locations.

In particular, a direct fired thermal oxidizer (dedicated incinerator) can be designed specifically for the required HVLC NCG flow. Lundberg Associates uses the HVLC NCG as combustion and/or cooling air for the incinerator when LVHC NCG and stripper off gases are also being burned. Not only is the HVLC NCG thoroughly combusted, but an additional fan for ambient air is often no longer required. Using the HVLC NCG as combustion air also reduces the incineration chamber and subsequent equipment sizes.

THERMAL OXIDATION OF DILUTE NCG IN RECOVERY BOILERS

As the Cluster Rules have required combustion of NCG, U.S. pulp mills have been searching for existing incineration locations to minimize capital costs. Although formerly avoided, the recovery boiler has become a primary choice for HVLC NCG incineration. The recovery boiler offers several locations for disposal of the NCG, including through the tertiary air system or a dedicated burner. A. H. Lundberg Associates has developed a safe and effective method for HVLC NCG incineration in the recovery boiler based on BLRBAC (Black Liquor Recovery Boiler Advisory Committee) recommendations.

Because the gases are to be burned in the recovery boiler, Lundberg Associates' NCG systems incorporate a series of interlocks and gas conditioning features designed to exclude the potential for water to enter the boiler. These are in addition to the safety features and interlocks typically included for NCG incineration systems.

At a recent system installation, the dilute NCG was collected, conditioned, and transported to the existing recovery boiler for injection through a dedicated burner. Since the HVLC NCG flow was relatively small, 2,000 ACFM (3,400 m^3/hr), and LVHC NCG was to be burned as well, a dedicated burner was a logical choice. An independent natural gas fuel train was supplied for the burner to provide a continuous pilot.

Furthermore, the gases were conditioned prior to the burner to prevent moisture from entering the boiler. First, the HVLC NCG was cooled in an indirect contact gas cooler. This vessel not only removes moisture from the gases, but it reduces the gas volume, allowing for smaller line sizes and equipment downstream. Next, the gases were motivated to the boiler with a steam ejector. Although fans are typically used in HVLC NCG applications, a steam ejector was used in this case due to the low gas flow. The HVLC gases were heated to 250ºF (120°C) in a shell and tube steam heater to further reduce the possibility of condensation. Prior to the heater, an entrainment separator was installed to remove any remaining moisture droplets.

Additionally, the piping was arranged so a minimum elevation distance existed between the boiler NCG firing nozzles and the rupture disc located in the respective piping system. The rupture disc serves as a mechanical means of ensuring that a slug of condensate contained in the NCG cannot be pushed into the recovery furnace. By arranging the piping such that the elevation differential between the firing nozzle and the rupture disc is in excess of the rupture disc burst pressure, a minimum safety factor is built into the system.

Similarly, dilute NCG was injected into the recovery boiler at another Lundberg Associates' NCG system installation. The HVLC NCG was collected from the decker hood, a spill collection tank, and a blow tank. Additional sources are to be added in the future. The NCG was sent through a cyclone separator to remove any entrained liquor or fiber, although typically direct contact fiber scrubbers or chevron entrainment separators are preferred for fiber removal. The gases were then cooled in an indirect contact gas cooler, motivated via an HVLC NCG fan, and heated to 150°F (65°C) prior to incineration. Entrainment separators were installed as well to remove excess moisture from the NCG. The gases were injected into the boiler tertiary air windbox through five independent ports. The tertiary air forced draft fan was tied into the HVLC NCG line to the boiler to ensure sufficient gas flow through the nozzles. The HVLC NCG was injected into the recovery boiler in such a manner as to ensure that boiler operation was not affected.

This multiple nozzle configuration was ideal due to the phased approach of installing the HVLC NCG system. Since the mill only wanted to collect three HVLC NCG sources initially and then add additional sources in the future, the multiple boiler nozzles made it possible. The required velocity and pressure drop through the nozzles could be met by using any combination of nozzles. This configuration allowed the collected gas flow to vary while evenly distributing the gases at the tertiary air level.

Other dilute NCG system features that preclude the possibility for carrying moisture into the boiler include low point drains and sloped piping. Low point, entrainment separator, and cooler drains are necessary to effectively remove condensate from the NCG. Also, the NCG lines are sloped in order to facilitate draining and avoid any low points in the piping. Lundberg Associates' HVLC NCG systems are designed with multiple safety features to prevent the possibility of moisture from entering the boiler.

In order to effectively incinerate the dilute noncondensible gases in the recovery boiler, care should be taken to sufficiently condition the gases to be transported without the possibility for condensation or moisture carryover into the boiler.

METHODS FOR REDUCTION IN THE VOLUME OF DILUTE NCG

In dilute noncondensible gas systems, the problem of excessive quantities of NCG requiring collection often arises. The HVLC NCG sources are typically large tanks or hoods that are not well sealed, allowing excess air infiltration. Once these sources are collected into the NCG system, the smallest leak, opening, or hole will bring excess air into the system since the sources are operated under vacuum. Also, the potential for washer hood doors to be left open can add to the quantity of air that must be collected. This requires that downstream equipment and piping be sized for the excess conditions, otherwise inadequate collection occurs. Several methods and techniques have been developed to minimize the HVLC NCG flow, thus producing a more manageable, cost-effective system.

For example, some existing brown stock washer hoods are being replaced with new low-infiltration washer hoods. These limit the amount of air that is drawn into the hood. Another method of minimizing the air intake to brown stock washer hoods is through reconfiguration of the air doctor fans. Typically, air doctor fans draw in ambient air to the washer hood to separate the sheet from the drum. This method brings additional unnecessary air into the system. A. H. Lundberg Associates has overcome this problem by using dirty air for the air doctor fans. At one particular installation, air was recirculated directly from the washer hood to the air doctor fan. This simple configuration did not require extensive modifications. Often, air doctor fans must be replaced with stainless steel units due to the corrosive nature of the recirculated gases. In addition, an entrainment separator is recommended upstream of the fan to prevent moisture from potentially damaging the fan. The entrainment separator and any low point drains can be drained back to the respective washer hood or filtrate tank.

Alternatively, the vent from the brown stock washer hood's respective filtrate tank can also be used to provide air to the air doctor fan. This method, however, generally requires that the filtrate tank be able to withstand slight pressure and vacuum conditions. Pressure vacuum relief devices can be supplied to protect the filtrate tanks. These can be water sealed or mechanical type relief devices. Both of these methods allow the air doctor fans to operate without bringing excess air into the HVLC NCG system.

Similarly to reduce the total HVLC NCG flow, the brown stock washer filtrate tanks can be vented directly to their respective washer hood, rather than collected as a separate HVLC NCG source. This helps minimize the HVLC NCG collection system, because the air is circulated between the washer hood and the filtrate tank. In this instance, the filtrate tank requires some pressure tolerance in order to maintain the NCG flow to the washer hood.

Pressure and vacuum protection on the tanks collected into the HVLC NCG system is another important aspect that contributes to the HVLC NCG flow. If the tank is only rated for atmospheric conditions, it cannot be sealed and collected, as the source will be under vacuum. Aside from modifying the tank structure, the only way to collect the tank is to sweep air into it. This involves installing an air intake on the tank to allow for ambient air infiltration. This is a cost-effective way to collect the NCG from an atmospheric tank without structural modifications. If the air intake is too large, however, collection of the HVLC NCG becomes nearly impossible due to the large ingress of air. Fugitive emissions from the tank can often be seen. This problem can be reduced through the use of a flapper type device located on the air intake. As a very slight vacuum develops in the collected tank, the flapper door will open to allow air to enter and prevent excess vacuum while restricting flow.

Other modifications can be made to ensure pressure and vacuum protection at the sources. A. H. Lundberg Associates has supplied similar flapper door type devices to allow for ambient air infiltration or tank venting on a continuous digester blow tank. These weighted mechanical devices were designed to relieve at either 5” (130 mm) water column pressure or vacuum to protect the tank. The weights on the flapper doors can be modified to vary the relief settings.

Ultimately, any modification that can be made to limit the amount of air infiltration to the HVLC NCG system will help minimize the capital costs. This includes smaller line sizes, smaller equipment downstream, reduced fuel usage for incineration, and a minimal impact at the incineration point.

EVAPORATOR INTEGRATED FOUL CONDENSATE STRIPPING SYSTEMS

A. H. Lundberg Associates has supplied multiple foul condensate steam stripping systems since the mandate of the MACT I requirements to efficiently treat contaminated kraft mill foul condensates, particularly those from the digester and the evaporators. Each system has been designed to meet the specific requirements of the mill, as well as to provide compliance with the MACT I regulations. Several systems have been designed to generate steam for use within the mill, while others are integrated into an existing evaporator system as a primary means of heat recovery. A secondary heat sink can also be implemented using water or black liquor in a trim reflux condenser.

The primary advantage to integrating an evaporator set into the stripping system is the ability to reuse the heat recovered through all the bodies of the evaporator set. Typically, it is desirable to integrate the stripping system reflux condenser with the first effect of the evaporator set. This allows the heat to be passed through to all the remaining effects, improving its economy. Heating liquor or boiler feed water, while efficient, does not produce the same effect through the rest of the evaporator set. The steam economy improves as the stripper integration is introduced sooner in the evaporator set. Figure 1 shows a typical flow diagram for an evaporator integrated steam stripping system.

One Lundberg Associates’ project in particular focused on integrating a new foul condensate stripping system into the existing six-effect evaporator set. The steam stripping system was designed for 500 gpm (31.5 lps) foul condensate. A falling film steam reboiler was included to allow for recovery of the steam condensate used for stripping, as well as to reduce the volume of stripped condensate. The reboiler is a shell and tube vessel with stripped condensate from the bottom of the column recycled on the tubeside to generate steam for stripping. Live steam is made up to the reboiler shellside to heat the stripped condensate. The primary reflux condenser was added to the evaporator set as a parallel first effect. The evaporator integration also included the supply of new first and sixth effect evaporator bodies to operate in parallel with the current arrangement. The existing first and second effects were changed to the new second effect 2AB and 2C bodies, while the third and fourth effects were changed to the new third effect

3A and 3B bodies. The result was a modified nine body six-effect system that can function with or without the stripping system in service.

The design of the evaporator modifications not only allowed for the steam stripping system to be integrated, but for a 25% increase in evaporator capacity as well. The heat from the stripper is recovered as additional evaporation in the new parallel first effect evaporator body. The vapor from the top of the stripping column is partially condensed in the new reflux condenser evaporator body. The heat contained in the overhead vapors is used to concentrate the liquor from 33.9% total solids to 36.2% total solids, with 27,607 lb/hr (12,520 kg/hr) of evaporation. The uncondensed vapor from the falling film reflux condenser is passed on to the trim reflux condenser where water is heated. The overall steam economy is 5.19 lb evaporation per lb steam. This is just slightly lower than the 5.53 steam economy when the evaporator set is run without the stripping system. The small decrease in economy is due to condensate preheat steam requirements in the stripper.

A falling film body was chosen as the new first effect body to be integrated into the stripping system. This technology offered the mill a high degree of turndown and thus, improved their ability to match the digester system's production rates. Another advantage of the falling film reflux condenser/evaporator body is the ability to operate with a very low temperature differential between the reflux vapor and the boiling liquor. The low temperature differential avoids subcooling of the reflux condensate and eliminates the possibility of generating red oil within the reflux loop.

Similarly, another recent project involved the integration of an evaporator body into a new foul condensate stripping system. This evaporator modification was necessary to justify the high design flow rate of 900 gpm (56.8 lps) foul condensate to the stripping system. The primary reflux condenser was integrated into the evaporator system as a parallel first effect. It was designed to evaporate liquor from the 2A effect evaporator body. The new primary reflux condenser/first effect was designed for 54,183 lb/hr (24,573 kg/hr) evaporation, increasing total solids from 38.5 to 42.5%. Liquor from the primary reflux condenser is then concentrated to 49.4% total solids in the first effect and sent to the product flash tank. Sample operating data from this stripping system are shown in Table 1 below.

Table 1: Evaporator Integrated Steam Stripping System - Sample Operating Data

Sample Date and Time	Steam Flow to Stripper (klbs/hr)	Cond. Flow to Stripper (gpm)	Methanol Conc. to Stripper (mg/L)	Methanol Conc. from Stripper (mg/L)	Methanol Removed (lb/day)	Removal Efficiency (%)
Design	85.3	900	2,530	126.5	25,944	95+%
8/27/01 8:00	51.3	475	3,695	73.7	20,609	98.0
8/29/01 8:00	53.8	485	3,834	70.0	21,860	98.2
8/31/01 8:00	55.1	524	4,268	114.0	26,098	97.3
9/10/01 8:00	55.1	501	3,584	66.6	21,098	98.1
9/12/01 8:00	61.1	550	3,417	56.0	22,145	98.4
9/13/01 7:35	60.0	600	3,358	155.5	23,021	95.4
9/13/01 9:00	58.0	600	3,199	149.9	21,918	95.3
9/13/01 10:30	56.0	600	3,297	176.0	22,435	94.7
9/13/01 12:00	54.0	600	3,224	193.1	21,788	94.0
9/13/01 13:30	52.0	600	3,188	306.0	20,717	90.4
9/13/01 15:00	50.0	600	3,313	370.0	21,156	88.8
10/1/01 8:00	59.9	540	3,341	52.4	21,261	98.4
10/3/01 8:00	59.7	524	3,484	60.2	21,512	98.3
10/4/01 8:00	59.5	524	3,087	42.7	19,097	98.6

This method of heat recovery from the stripping system was also beneficial in that it simultaneously increased the capacity of the evaporator set. Other modifications were made to the evaporators to allow for the capacity increase. These upgrades included a new parallel first effect evaporator body and reconditioning of the existing liquor heater. The result was an eight body six-effect system. The steam economy of the system is currently 3.94 lb evaporation per lb steam, including the steam required to operate the stripping system. The steam economy is based upon theoretical steam requirements, and does not include venting or radiation losses.

Furthermore, the reflux condenser in a steam stripping system can be designed to generate clean steam. The stripping system essentially acts as a pressure reducing station when a steam generator is used. Often a reboiler is included with the stripping system to provide feed water to the steam generator. This practice permits the recovery of the sensible heat from the steam condensate and maximizes steam generation. For instance, Lundberg Associates installed a 500 gpm (31.5 lps) steam stripping system to operate with 47,222 lb/hr (21,420 kg/hr) of 60 psig (414 kPa) steam to the reboiler. The falling film reflux condenser/steam generator partially condensed the vapors from the top of the stripping column to produce 39,026 lb/hr (17,702 kg/hr) steam at 30 psig (207 kPa). The uncondensed vapor is passed on to the trim condenser. Table 2 provides sample operating data from this stripping system with steam generation.

Table 2: Steam Stripping System with Steam Generation
Sample Operating Data

Sample Date and Time	Cond. Flow to Stripper (gpm)	Steam Flow to Reboiler (klbs/hr)	Steam Flow from Steam Generator (klbs/hr)	Steam Outlet Pressure from Steam Generator (psig)
Design	500	47.2	39.0	30.0
4/11/01 14:55	521	48.4	45.6	30.0
4/11/01 16:50	517	49.7	48.1	30.1
4/11/01 17:26	521	41.0	35.5	30.1
4/11/01 17:50	521	50.7	45.7	30.1

The steam stripping system can be designed to operate at even higher pressures to produce higher pressure steam. One such project produced 60 psig (414 kPa) steam from the reflux condenser/steam generator with 132 psig (910 kPa) steam to the reboiler. This 600 gpm stripping system produced 58,360 lb/hr (26,472 kg/hr) steam at 60 psig (414 kPa) with 68,710 lb/hr (31,166 kg/hr) steam at 132 psig (910 kPa) to the reboiler. Generating clean steam is a thermally efficient method of recovering the heat from a foul condensate stripping system. The small losses in efficiency are due to the thermal value of the steam and the lost preheating requirements.

Clearly, the integration of a steam stripping system with an evaporator set or for the production of steam is an efficient way to recover and utilize heat.

STRIPPER OFF-GAS AS FUEL FOR DIRECT FIRED THERMAL OXIDIZERS

With the increase in the number of steam stripping systems in the U.S., the methods for handling and incineration of stripper off gas (SOG) have come under focus. As with LVHC and HVLC NCG, the stripper off gases must be properly conditioned and transported for incineration. Stripper off gas, however, must be handled separately from the other types of NCG. SOG can be incinerated in various locations, including boilers, lime kilns, and dedicated incinerators. A dedicated incinerator is often a primary choice for incineration of the SOG due to its ability to be used as fuel.

The cost of operating a dedicated incinerator can be reduced using stripper off-gas (SOG) as fuel. A. H. Lundberg Associates' incinerator burners are designed to use both natural gas (or fuel oil) and stripper off gas for combustion of the NCG. The stripping system is designed to produce SOG at 50 wt% methanol to ensure that there is enough methanol in the SOG to serve as fuel. The fuel value of SOG at 50% methanol is generally sufficient to limit the use of natural gas to the minimum natural gas flow required for low fire conditions. The stripper off gas is piped to both a port on the burner and the incineration chamber. The incinerator can operate with or without the use of stripper off gas as fuel. The incinerator uses natural gas (or other auxiliary fuel) in the event the SOG is not available or ready for use as the primary fuel (i.e. stripper start-up and shutdown conditions).

For instance, one recent dedicated incinerator installation included burning of LVHC NCG, HVLC NCG, and SOG. The normal natural gas flow to the burner is 33 SCFM (56 Nm^3/hr) using SOG as fuel. In the event that SOG is not available, the natural gas requirement increases by more than ten times to 350 SCFM (595 Nm^3/hr). At a similar dedicated incinerator installation, the minimum natural gas flow with SOG as fuel is 40 SCFM (68 Nm^3/hr); without SOG, the required natural gas flow is 500 SCFM (850 Nm^3/hr). The large fuel requirement increase is due to the large quantity of HVLC NCG that must be heated and completely combusted. Clearly, these examples demonstrate the economic benefits of operating the dedicated incinerator with stripper off gas as fuel.

WASTE HEAT BOILERS ON DIRECT FIRED THERMAL OXIDIZERS

With the mandate of the Cluster Rules, pulp mills have been forced to find suitable locations for burning their noncondensible gases. Direct fired thermal oxidizers, or dedicated incinerators, have become a popular method for disposing of these hazardous gases. In order to earn back the cost of these dedicated incineration systems, several installations have included a waste heat boiler to generate clean steam with the hot waste gases. Figure 2 shows a standard dedicated incinerator and waste heat boiler arrangement.

A waste heat boiler is only a worthwhile investment if there is enough heating value in the gases to justify the cost of the boiler. With a small incinerator or relatively low flow waste gas streams, the investment for a waste heat boiler is not justified. However, with large quantities of HVLC NCG or high combustion/cooling air requirements to a dedicated incinerator, the investment of a waste heat boiler becomes warranted.

For example, at one Lundberg Associates' dedicated incinerator installation, a waste heat boiler was supplied to generate 20,200 lb/hr (9,160 kg/hr) steam at 180 psig (1,240 kPa). The dedicated incinerator was designed to handle 3,650 ACFM (6,200 m^3/hr) of LVHC NCG, 1,325 lb/hr (600 kg/hr) of 50 wt% methanol SOG, and 13,500 ACFM (22,935 m^3/hr) of HVLC NCG. Only 40 SCFM (68 Nm^3/hr) of natural gas is required with SOG as auxiliary fuel. With the large HVLC NCG flow that must be heated to 1,600ºF (870°C) for 0.75 seconds in order to meet Cluster Rule requirements, there is sufficient heat available to produce steam.

First, the NCG is combusted in the incineration chamber at the required time and temperature, and then transported to the waste heat boiler via a brick-lined hot gas transition duct. The waste heat boiler is a fire tube type boiler with an integral steam drum. It is constructed of all carbon steel with a refractory lined gas inlet chamber (smoke box). Hot gas from the incinerator is used to evaporate boiler feed water to produce steam. A typical installation includes a blowdown separator as well as the boiler trim. The blowdown separator is provided as a flash chamber for the waste heat boiler's blowdown water. The flash steam from the separator is vented to the atmosphere. The remaining blowdown water is cooled in an aftercooler that is integral with the separator drain connection and then sewered. The cooled gases exit the waste heat boiler at approximately 500ºF (260°C). This temperature must remain high in order to stay above the dew point of SO_3. Only high pressure steam is produced in the waste heat boiler for this same reason. Finally, the gases are further cooled in a direct contact Hastelloy quench before being sent to the SO_2 scrubber.

At another Lundberg Associates' dedicated incinerator installation, a waste heat boiler was included to produce 23,500 lb/hr (10,658 kg/hr) steam at 165 psig (1,138 kPa). The incinerator was designed to

combust only LVHC NCG and SOG. Due to the high heat content of these gases, however, a large combustion and cooling air requirement of 12,000 SCFM (20,387 Nm^3/hr) is necessary. This large flow of air must be heated to 1600ºF (870°C) for 0.75 seconds as well, so it is desirable to recover this heat. This is accomplished in the waste heat boiler. By generating clean steam, a waste heat boiler is an ideal way to recover some of the costs of a dedicated incinerator.

CONCLUSION

Overall, Lundberg Associates' expertise in meeting the Cluster Rule requirements in the U.S.A. will be applicable to future environmental projects in Chile. The possibilities range from thermal efficient steam stripping systems to collection and incineration of noncondensible gases. The cost effective solutions outlined above have already been implemented in the recent surge of environmental system upgrades.

Future environmental projects in Chile that focus on condensate treatment or noncondensible gas collection and incineration can utilize the technology implemented over the past several years, as well as in the years to come. This technology includes combustion of dilute NCG in the recovery boiler and the methods for reducing the noncondensible gas source flows. Also, foul condensate steam stripping systems can be integrated into existing evaporator sets to provide improved heat economy. Dedicated incinerators can be operated with stripper off gas as fuel to provide natural gas savings. Additionally, a waste heat boiler can be supplied to recover some of the costs for installing a direct fired thermal oxidizer. Each of these examples promotes cost savings to help overcome the investment required for environmental systems. These techniques can be applied to future Chilean environmental projects.

EXHIBIT B

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COLLECTION AND INCINERATION OF HIGH VOLUME-LOW CONCENTRATION PULP MILL NONCONDENSIBLE GASES

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Michael Crenshaw — Packaging Corporation of America

Abstract

High Volume-Low Concentration gases are collected at the Packaging Corporation of America (PCA) mill at Valdosta, Georgia. After collection and cooling, pulp mill HVLC gases are incinerated in one of two existing waste wood boilers which required no significant modifications in either equipment or operation. Successful collection of HVLC gases is dependent on having reasonable estimations of temperature and flow rates, evaluation of the streams for possible contaminants, and control of condensates generated during transport. Successful incineration of HVLC gases is dependent on judicious selection of incineration locations that can handle large volumes of HVLC gas on a continuous basis. Finally, safety must be given the highest priority in the design and operation of HVLC collection and incineration systems.

Introduction

During the past several years, many pulp mills have installed systems for the collection, treatment, and disposal of noncondensible gases (NCG) generated during the pulping process. Most recently, these systems have included provisions for the collection and disposal of High Volume–Low Concentration (HVLC) gases. The PCA mill in Valdosta, Georgia installed an HVLC collection and incineration system as a part of a larger project involving the addition of a new pulp washing line. The system was later modified to include a dedicated incinerator for incineration of these gases, together with other pulp mill noncondensible gases.

As the environmental climate continues to change, HVLC collection and incineration will continue to receive more attention. The collection of dilute gases requires specialized consideration, necessitating careful attention during all phases of the project. Through sound design, the safe and efficient collection of HVLC gases can be accomplished.

General Design Criteria for High Volume-Low Concentration NCG Systems

Pulp mill NCG sources can be broken down into three (3) categories. The first category is the LVHC gases; examples of typical sources are shown in Table I. The second category is the HVLC gases, examples of which can also be found in Table I. The third category is overhead vapors from a steam stripping system for foul condensate. These vapors are a mixture of methanol, water, and TRS gases.

Table I – Typical NCG System Sources

LVHC GAS SOURCES	HVLC GAS SOURCES
Turpentine Recovery Vent	Black Liquor Oxidation Vent
Blow Heat Recovery Vent	Soap Skimming Tanks
Evaporator Hotwell Vents	Black Liquor Storage Tanks
Foul Condensate Storage Tanks	Brown Stock Washer Filtrate Tanks
Continuous Digester Relief	Brown Stock Washer Hoods
	Knotter (Screen) Hoods
	Chip Bins
	Contaminated Condensate Tanks
	Air Stripping Equipment

The historical emphasis has been on the collection of the first and third categories of sources. Only new mills and major mill expansions have been required to include the collection of HVLC sources. However, new regulations will soon require all mills to include collection of HVLC sources as a part of their mill-wide NCG collection and disposal system.

Characteristics of High Volume–Low Concentration Gases

The pulp mill gas streams that are collected into the HVLC NCG system produce a gas stream that is predominantly air, but includes small amounts of compounds known collectively as Total Reduced Sulfur (TRS) and Volatile Organic Compounds (VOC). TRS compounds include hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. VOC includes methanol, acetone, and turpentine.

The first and most important characteristic of HVLC gases is that the concentration of components in these streams falls well below the lower explosion limits (LEL). Still, the TRS compounds present are noxious and have a very low threshold of odor detectability, resulting in the need for their collection and disposal.

The second characteristic of HVLC gases is the high gas volumes associated with these sources. The total volume of the combined HVLC sources, often in the range of 15,000-20,000 m^3/hr and potentially much higher, requires that the gas treatment methods and the disposal methods be given careful consideration.

Collection of High Volume–Low Concentration Gases

For new pulp mills, the need for collection of HVLC gases from sources must be considered in initial design of the collection points. Storage tanks can be designed to be completely sealed from the atmosphere to minimize the volume of HVLC gases by not allowing excess air to be pulled into the tank by the gas fan. Source collection points should be designed to withstand slight vacuum conditions of up to 3 kPa gage.

Retrofits to existing systems can sometimes be difficult because source equipment was not originally designed to withstand vacuum conditions. In some cases it is possible to avoid modifying or replacing existing equipment by using a sweeping action to remove the HVLC gases from the equipment. This requires a second equipment vent, open to atmosphere, through which some air is drawn into the equipment. If the atmospheric and HVLC vents are properly located, HVLC gases can be effectively purged from the equipment without releasing any gas to the atmosphere. This does result in additional overall capacity required for the HVLC system due to the additional air added and should be used only if absolutely necessary.

In either case, new or existing sources, it is critical to have reasonable estimates of the expected flow and temperature of each HVLC NCG source. Failure to properly analyze the amount of gases that will be present can result in an expensive, oversized system, or worse, a system which is undersized and not capable of collecting all of the gases which are being generated from the various sources.

Treatment of High Volume–Low Concentration Gases

Treatment of noncondensible gases typically takes one of three forms. The first is scrubbing with white liquor or caustic to remove soluble TRS compounds. The second is removal of entrained fiber or foam using direct contact scrubbers, mechanical foam breakers or cyclone separators. Third is the use of indirect contact coolers which remove excess water vapor and other condensable from the gases and reduce the volume of gases to be handled downstream.

HVLC systems typically do not employ white liquor scrubbers. Since there is a relatively small amount of TRS compounds present in the gases, the benefit of removing these compounds does not justify the cost of providing a large scrubber. More commonly, direct contact scrubbers are used as fiber removal devices. Because of the possibility of foam carryover, HVLC sources should utilize either mechanical foambreakers or cyclone separators to prevent foam from entering the HVLC system.

The use of indirect contact coolers is quite common in HVLC systems. Many of the sources of HVLC gas listed in Table I will have normal temperatures in the range of 80-90° C. At these temperatures, the HVLC gases carry a significant amount of water vapor and have a large specific volume. For example, reducing the temperature of a typical HVLC gas stream from 90 °C to 50° C will remove 94% of the water vapor present and reduce the gas volume by 68%. This will result in less dead load from water vapor at the incineration point and will quite possibly reduce the size of piping and equipment downstream of the cooler, resulting in significant cost savings.

Motivation of High Volume–Low Concentration Gases

HVLC gases can be transported through the system using either steam ejectors or fans. Steam ejectors are preferred because there is little potential for generating a spark which in turn could ignite the HVLC gas. However, the typical high gas volume of an HVLC system precludes the use of a steam ejector, so fans are typically used. Care must be taken in the selection and installation of the fan in order to minimize the risk of an explosion should unusual conditions cause the LEL to be exceeded.

Incineration of High Volume–Low Concentration Gases

The three typical locations for NCG incineration include lime kilns, power or waste wood boilers, and dedicated incinerators. The high gas volumes in the HVLC system make it difficult to use the lime kiln as an incineration point. This is because the volume of gases to be incinerated is often a significant portion – possibly even a majority – of the total air requirements to the kiln. Using the lime kiln as an HVLC incineration point greatly reduces the flexibility of the kiln for its primary purpose.

Power boilers or waste wood boilers can easily handle large HVLC gas volumes and deserve consideration as prime candidates for points of HVLC incineration. To assist in maintaining good combustion efficiencies with these boilers, a steam coil air heater can be used on the HVLC gases prior to their introduction into the boiler. This also reduces the potential for corrosion in the carbon steel entry ducts.

However, when using a boiler as an incineration point, the presence of TRS compounds in the HVLC gases can have two negative effects. The first is the possible long term corrosion effects from the sulfur. The second is that the sulfur added from the HVLC gas stream will leave the boiler as SO2 in the stack gases. This may result in having to add new SO2 removal and/or analysis equipment to a boiler where none was previously required.

Increased emphasis on mill-wide air pollution controls will make dedicated incinerators increasingly more important in the coming years. An incinerator can be designed specifically to meet the needs of the HVLC gases. Further, the inclusion of HVLC gases in an incinerator which is also used to destroy LVHC and stripper overhead gases will complement the overall performance of the system. The high volume of low fuel content HVLC gas serves as combustion and cooling air for the other NCG streams. Conversely, the high heat value of the LVHC and stripper overhead streams greatly reduces the amount of fuel which would otherwise be required to incinerate HVLC gases alone.

The main disadvantages of choosing an incinerator as an incineration point are its requirements for significant initial capital expenditure and its continuing operating costs. The operating costs with respect to fuel can be greatly reduced if a high quality stripper overhead gas stream is available for use as a supplemental fuel.

Safety in the High Volume–Low Concentration System

The HVLC gases described earlier contain TRS compounds which can be hazardous to life and/or property, even at the low concentration present. A properly designed HVLC system will include the following features to address these safety concerns.

1. Mixing of different types of gas streams is not advised. The HVLC gases could dilute the LVHC gases into the explosive range where they become more dangerous to handle. Mixing of either HVLC or LVHC gases with stripper overhead gases may condense stripper overheads and can cause two-phase flows in piping and low NCG velocities.
2. Piping velocities should be maintained to ensure that gases are moving above the flame propagation speed of the TRS components. Typically these velocities should be several times the flame propagation speed of the gases. It is possible to design an NCG system with piping velocities above the flame propagation speed of TRS compounds, but not above the flame propagation speed of turpentine. Every effort must therefore be made to prevent any accumulation of condensate and/or turpentine throughout the system.
3. Piping systems must be further designed so that condensate is not allowed to collect in the piping. If allowed to collect in the piping, two problems can occur; 1) flow can be stopped due to a condensate “plug” and/or 2) turpentine can collect on the surfaces of any accumulated condensate. All piping low points, even small piping connections at the bottom of a pipe, must be drained into a sealed condensate collection tank.
4. Flame arresting devices should be installed at each incineration point. Care should be taken to choose and install flame arresters so that condensate cannot collect within the flame arrester. Also, flame arresters should be designed with large air passages which minimize pluggage and restriction to flow.
5. Pressure relief devices are also important at the individual sources and near the incineration points. High pressure means that either a restriction has occurred in the piping or combustion is occurring. Due to the hazards associated with high pressure, the system must be designed to recognize and react to the high pressure by venting the gases and alerting the operations personnel that venting has occurred because of high pressure. Pressure switches can be effectively used to monitor pressure within HVLC systems and are used with pressure relief safety devices like rupture discs.
6. Entrainment separation equipment is important to prevent entrained particles from blocking flame scanning equipment within the incineration locations. They can also be excellent locations for a low point drain within the piping. Entrainment separators minimize erosion damage, particularly when installed on the suction side of the HVLC system motive fan.
7. Local vent stations, either manual or automatic, should be provided to allow for proper operational flexibility as well as proper isolation for maintenance.

8. The use of a properly designed system of interlocks, "permissives", and control logic can prevent damage to the system and greatly reduce the potential for significant (and/or catastrophic) accidents. Safety features provided by the interlock system include:
   - The "fail safe" position of the system should vent the HVLC gases to the atmosphere. The failure position of control valves and other instruments should allow the HVLC gases to vent to the atmosphere if electrical control power or instrument air is lost, or if the system interlocks are activated.
   - Loss of flame as indicated by flame detection equipment will cause the system to vent to atmosphere. When a boiler is used as the incineration point, a minimum steam output is required to maintain HVLC gas incineration.
   - If a steam ejector is used as the motive force, then either low steam flow or low steam pressure will cause the HVLC gases to vent. If a fan is used, the fan speed should be monitored and HVLC gases should trip at the first signs of fan failure.
   - Low HVLC flow at the incineration point will cause the collected gases to vent.
   - High temperature in a collection line approaching the incineration point indicates a possible burnback and will cause the HVLC gases to vent to atmosphere.
   - High pressure at any source or near incineration points will cause the HVLC gases to vent. The causes of high pressure, such as line blockage or combustion, are important enough that redundant methods should be employed to ensure that the high pressure is relieved.

The Packaging Corporation of America HVLC System in Valdosta, Georgia

The HVLC system in Valdosta, Georgia was originally started up in April 1991. The system collects gases from seven sources. Six of these are new sources associated with a new pulp washing line. The seventh source is an existing batch digester evacuation system. Figure 1 is a flow diagram of the HVLC collection system as originally installed, including the incineration portion of the system. The pulp washer project also included the addition of new batch digester capacity. Therefore, it was necessary to install a new LVHC NCG system for the collection of the gases generated during the digester blows in addition to the new HVLC NCG system. A blow heat recovery system was also added to condense and utilize the heat released during the digester blows and to concentrate the NCG into a form which can be easily handled. The new HVLC NCG, LVHC NCG, and Blow Heat Recovery systems were all designed, supplied, and installed by A. H. Lundberg Associates, Inc. under a turnkey contract.

System Overview

It was initially determined that fiber carryover would not be a problem from any of these sources, so no direct contact scrubber was provided. Two sources were deemed likely to contain foam carryover, so mechanical foambreakers were added on these tank vents. The combined HVLC sources had a design temperature of 82° C. A cooler was installed to reduce the HVLC gas temperature to 49° C. This temperature reduction decreased the amount of water vapor in the gas by 87% and reduced the volume by 50%. Just as important, the downstream line size was reduced from 24″ to 20″ in diameter. This resulted in a significant cost savings since there was approximately 250 m of pipe installed downstream of the cooler. The decreased volumetric flow also decreased the required size of flame arresters and control valves, and reduced the motive fan horsepower.

Due to the high volume of the gases, approximately 10,000 m^3/hr even after the cooler, a fan was selected as the motive force for the gases. The fan, constructed of T-304 SS, is located near the bark boilers which were selected as incineration points. This allowed the vast majority of the system piping to remain under vacuum conditions so that any leaks would further dilute the already low concentration gases, and further, would not allow escape of the gases to the atmosphere.

Two bark boilers were selected as primary and secondary incineration points for the HVLC gases in the initial project. The boilers were selected because of their reliability – at least one was always in service – and because of their ability to absorb the total HVLC flow as a reasonable proportion of the total combustion air flow.

The HVLC system includes an air make-up system that allows the HVLC gas flow to act as a constant source of combustion air. HVLC sources seldom operate at a constant, steady flow rate. Rather, they swing widely depending on production rate, tank levels, and other mill processes. These swings would be difficult to absorb in any of the incineration points, possibly resulting in inefficient combustion. To avoid this situation, the design flow of HVLC into the incineration point is selected to be slightly higher than the total output from the HVLC sources. Atmospheric air is added to the system to meet the desired flow into the incineration point, providing a constant flow of combustion air for the incineration point.

In order to remove entrained moisture droplets, chevron style mist eliminators were installed immediately upstream of the motive fan, as well as at each incineration point. The separator in front of the fan is especially important in order to avoid erosion of the fan blades by water droplet impingement.

The modifications required to add the HVLC gases to the existing boilers were very minor. After consultation with the original boiler manufacturer, it was determined that the HVLC gases would be added to the Forced Draft Fan discharge duct prior to entering the air preheat section. This allowed the HVLC gases to be preheated along with the rest of the boiler combustion air. The only modification required to the boilers was a 20″ tie-in for the HVLC NCG duct into the boiler combustion air duct.

Within one day of starting the HVLC system, the entire system had been placed on line and was being operated by the mill operators. There was no noticeable effect on the boiler operation, either in terms of capacity or operability. Further, the amount of SO_2 released from the boiler stacks increased only marginally and was considerably lower than the normal amount of SO_2 generated when the boilers switch to use fuel oil as the fuel source.

Recent System Improvements and Additions

In October 1992, in conjunction with the installation of a new lime kiln, PCA installed a dedicated NCG incinerator at Valdosta. As is the case with many mills, PCA had continued to add NCG sources over the years as new systems were installed or in order to meet new requirements. The result was a system with four different collection systems with normal incineration at four different points. Because the new lime kiln was replacing two existing kilns which were LVHC NCG incineration points, it was necessary to find a new primary and secondary incineration point for these NCG streams. PCA elected to install a new dedicated incinerator as the primary incineration point. Figure 2 illustrates the various other system modifications and Figure 3 is a flow diagram of the incinerator. The new lime kiln would be the back-up incineration point for the LVHC NCG and for the stripper overhead gases, while the waste wood boilers continue to back up the incinerator for the HVLC gases. The new incinerator, as well as the modifications to the existing NCG system, was designed and supplied by A. H. Lundberg Associates, Inc. under a turnkey engineering contract.

By combining all of the NCG streams into a single primary incineration point, PCA was able to take advantage of the complimentary nature of the HVLC gases with the LVHC and stripper overhead gases.

The result is a system which does not require a tremendous amount of fuel to incinerate the HVLC and is also able to utilize the HVLC gas stream as combustion air for the other noncondensible gases.

Conclusions

The collection and incineration of High Volume–Low Concentration noncondensible gases generated in the pulp mill is likely to become very common in all pulp mills as new environmental regulations are issued requiring stricter air and water emissions compliance. The addition of HVLC collection systems should be considered integrally with other types of NCG systems in order to achieve the most efficient operation. Careful consideration should be given in the initial design phase to ensure that the HVLC system will have adequate capacity. New systems must also consider what level of treatment is required for the specific gases to be collected, particularly in the areas of contaminant removal and gas cooling. The selection of an incineration point must allow for the large quantity of low heat value gases contained in the HVLC gas streams. Finally, and most importantly, the HVLC system must incorporate safety features which will allow easy operation of the system and yet consider the fact that HVLC NCG is hazardous and can cause damage to life or property if not handled properly.

EXHIBIT C

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- ❑ POLLUTION CONTROL
  - ❑ Black Liquor Oxidation ❑ Weak ❑ Strong
  - ❑ Condensate Stripping ❑ Steam ❑ Air
  - ❑ TRS ❑ MeOH / BOD ❑ COD
  - ❑ Noncondensible Gas ❑ Collection ❑ Incineration ❑ Scrubbers
  - ❑ Strong ❑ Dilute ❑ SOG
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EXHIBIT D

A. H. LUNDBERG ASSOCIATES, INC.

J-895386

February 22, 1991

OPERATING AND MAINTENANCE MANUAL

LOW VOLUME HIGH CONCENTRATION NONCONDENSIBLE GAS COLLECTION AND INCINERATION

(Begins at Secondary Condenser Outlet)

PACKAGING CORPORATION OF AMERICA

VALDOSTA, GEORGIA

TABLE OF CONTENTS

I. INTRODUCTION

A. H. Lundberg Associates, Inc. has supplied a Blow Heat Recovery and a Noncondensible Gas Collection and Incineration System to the Packaging Corporation of America mill in Valdosta, Georgia. This manual contains the operation and maintenance instructions for the LVHC (Strong) NCG System. The operation and maintenance instructions for the Blow Heat Recovery System and the HVLC (Dilute) NCG System are contained in separate manuals.

During the pulping process, malodorous gases and BOD requiring compounds are formed and Federal regulations restricting their discharge are being promulgated. These compounds are contained in large volumes of weak black liquor and digester blow gases. The systems and equipment which have been supplied comprise the plants required to recover and concentrate these compounds and complete their processing.

The purpose of the Strong NCG System is to collect the noncondensible gases from the Blow Heat Recovery System and process these gases to reduce emissions of the foul and malodorous gases. As these gases are potentially explosive, safety is a primary concern in the design of the NCG System. Proper operation and maintenance of the NCG System is required in order to minimize emissions of these gases to the atmosphere while providing a safe environment.

II. PROCESS DESCRIPTION

A. General Description

(Refer to Flowsheet AL-895386-01, Sht 2/4)

The Noncondensible Gas Collection and Incineration System (NCG System) is designed to collect, transfer and incinerate the malodorous and gaseous byproducts of the pulping process.

The Strong NCG System collects gases from the Blow Heat Recovery System for incineration. The NCG is collected and transferred to an incineration point, either the Riley Bark Boiler or the C-E Bark Boiler. At the incineration point the gases are incinerated (oxidized) to harmless and nonobjectionable gases. In this system, either the Riley Bark Boiler or the C-E Bark Boiler can be used as the incineration point

The NCG System is designed with corrosion resistant stainless steel hardware and multiple safety features. An interlock system insures that all of the proper operating conditions are present before the gas is collected and introduced to the incineration point. These interlocks will also shut down the system and vent the noncondensible gases to the atmosphere if an upset condition occurs while the gases are being incinerated.

Since the noncondensible gases are flammable, the NCG System has several features designed to prevent ignition or minimize any potential damage. These features consist of: flame arresters to stop flame movement through a pipe, rupture discs to relieve pressure, and a flashback alarm system to sense flashbacks from the incineration point.

All of the remotely operated valves are designed to fail mechanically so that the noncondensible gases are vented to the atmosphere in the event of a pneumatic or electrical power loss.

Instrumentation has been installed to monitor the operation of the system and record process data.

B. Safety Aspects

1. Toxicity

The gases being piped by the NCG system are considered as toxic and lethal. Breathing the gases may result in physical harm. Extreme care must be taken in the presence of any leak in the noncondensible gas system. The lines should be well purged before they are disconnected for maintenance or other reasons. (steam purged)

The NCG system is designed to be pressure-tight. It is also designed to last many years without deterioration through the use of stainless steel fittings, piping, and hardware with TFE gaskets, and mechanical fail-safe equipment. However, care must be exercised during maintenance operations to insure the mechanical and interlock integrity of the system.

Normal toxic gas precautions should be employed when operating or maintaining the noncondensible gas system.

2. Flammability

The nature of the noncondensible gases is to be extremely flammable. The design of the system includes multiple backup systems to insure the greatest amount of flame safeguards and to minimize any remotely possible damage. These include:

a. The noncondensible gases from the Blow Heat Recovery System is a fuel rich mixture with insufficient air to support combustion under normal conditions. In the unlikely event that ignition occurs in the piping system, the conditions will not support combustion. It should be stressed that the noncondensible gases being piped are fuels. Leaks in the system should be fixed at once to prevent the fire hazard presented by leaking gases.

b. Interlock System: An electrical interlock system coupled with a mechanical fail-safe design is provided to insure that all of the proper operating conditions exist before the system can be operated. Should any one condition go to abnormal, the system will automatically revert to atmospheric venting, blocking gas delivery to the incineration point.

* c. Alarm System: The alarm system is designed to warn the operators of any sensitive condition. It is another method of preventing or minimizing ignition damage. including any ventfire

d. Flame Arresters: These flow through devices placed at strategic locations in the system are designed to block the propagation of the flame in the noncondensible gas system. These cylindrical devices have a core of thin gauge stainless steel to serve as the arresting method. The flame arresters are intended to:

1. Dissipate the heat of combustion as rapidly as possible by large surface area to act as a heat sink.

2. Disrupt the shock front associated with flame propagation.

e. Rupture Discs: Rupture discs have been situated near potential sources of ignition to relieve sudden pressure buildups. The discs have been designed to rupture at 10 psig. These devices require no maintenance or operator attention except annual debris cleaning around them and their protective stacks.

Alarm if burst.

Normal fire precautions should be followed in the vicinity of the discs including limitations on smoking, welding, grinding, and similar operations.

f. Flashback Alarm System: Another part of the alarm system is the flashback alarm designed to monitor temperature within the piping. Set to trip at 350°F, the system would indicate the presence of flame within the pipe due to a flashback from the incineration point. When the set point is reached, the alarm will sound and the system will automatically divert gases through the atmosphere vent at the ejector area. A steam purge will then automatically purge any remaining gases between the shut-off valve and the incineration point.

III. EQUIPMENT DESCRIPTION

A description of the equipment is presented to familiarize the operators and maintenance personnel with the noncondensible gas system. All personnel involved with the noncondensible gas system are encouraged to read this manual and to refer to it as needed.

A. Piping and Valves

The piping used throughout the noncondensible gas system is made of stainless steel for long term corrosion protection. Gasket materials vary with the conditions, temperature and pressure, at the particular locations. Gaskets in contact with NCG should be Gylon or reinforced teflon.

All of the valves used to control the flow of the noncondensible gases have stainless steel bodies and TFE or stainless steel seats. The automatic valves are all pneumatically operated. Depending on the purpose of the valve, it may either be a fail-open or a fail-closed valve with the emphasis being on safety. The functions of the control valves are given below in Paragraph "J". The operation of these valves is controlled through safety interlocks in the distributed control system, which is located in the control room for that area.

B. Flame Arresters (O-8001, O-8002, O-8003)

The flame arresters have T-316 stainless steel wetted parts and a flow through design. A large diameter center section holds a rolled up stainless steel pack used to dissipate heat and break up shock waves. Eccentric reducers are used at each end to prevent condensate from accumulating in the housing.

Although the flame arresters are inert devices needing no operator attention, they may need routine cleaning to prevent buildup of deposits from the gas stream. A buildup of deposits is detected by measuring an increased pressure drop through the flame arrester. Taps are provided on the flame arrester for periodic testing or installation of a differential pressure gauge. A six month inspection interval is recommended initially unless greater or lesser amounts of buildup show a different time interval is needed.

A 1/2 inch NPT coupling is provided on each side of the arrester for measuring differential pressure across the center section. A differential pressure of 1-1/2 to 2 inches of water indicates that the flame arrester core should be inspected and cleaned during the next scheduled shutdown. The core should be steam cleaned.

C. Rupture Discs

Rupture discs have been provided to relieve line pressure at 10 psig. The discs are made of graphite and are installed with pressure switches which alarm when line pressure approaches 7 psi. The system should not be re-started after a rupture disc failure until the cause of the pressure build-up has been determined and the disc(s) replaced.

Rust plan called for optical sensors upon rupture. Can this be done?

D. Steam Ejector (O-4001)

A steam ejector is used to provide the motive force to transfer the gases from the sources to the incineration points. The ejector is constructed of stainless steel for corrosion protection and long life. It is designed to operate on 160 psig steam. Steam pressures lower than 130 psig will significantly reduce the capacity of the ejectors.

E. Distributed Control System/Discrete Logic

The discrete logic portion of the control system is the operating heart of the noncondensible gas system. All of the system interlocks are programmed into the discrete logic. All critical operator commands are also processed here. If an unsafe or upset condition exists, the control system will prevent any command to collect or burn the gases from being executed. The NCG system will be controlled through the Bailey Net90 in the power house and digester areas.

F. Gas Cooler (354)

The Gas Cooler is an indirect contact unit of shell and tube design. The purpose of the cooler is to remove the majority of the water vapor in the NCG and reduce the gas volume flow. The NCG flows through the tubes to condense out the water, with the counter flow cooling water on the shellside. The cooling water flow is controlled by the exit NCG temperature setpoint.

G. Gas Scrubber (355)

The Gas Scrubber is a packed column designed to remove ionizable sulphur from the NCG using white liquor as a scrubbing medium. This also increases sulphidity in the white liquor and prevents sulphur loss from the system.

1. White Liquor Supply Pump (366)
   This pump accepts white liquor from the main white liquor storage tanks and feeds the Gas Scrubber.

2. White Liquor Return Pump (367)
   This pump returns the white liquor from the Gas Scrubber to the white liquor storage tanks.

H. Mist Eliminator (O-7001, O-7002)

The mist eliminator is a chevron type device to remove condensed water and other entrained liquids from the line just ahead of the incineration point.

I. Alarm System

The alarm system is designed to activate under the following upset conditions, these conditions will also cause the system to vent automatically:

auto vent at Boilers 1. Low steam production or flameout in the incineration point.

Boilers 2. Flashback in the line to the incineration point.

? 3. Low steam pressure to the ejector.

? 4. Low steam flow to the ejector.

Boilers? 5. Low noncondensible gas flow from the ejector.

? 6. High pressure near any rupture disc.

Digester 7. High level or high differential pressure at the white liquor scrubber.

What about PRV? What about loss of White Liquor flow? What about emerg. vent ahead of scrubber? What about manual vent — to keep oper. aware?

J. Instrumentation

The NCG system has instrumentation to monitor and control the operation. Much of the instrumentation consists of remotely operated control valves, pressure indicators, and temperature indicators. A description of the control loops is given below. It is important to note that whenever gases are venting to the atmosphere, the NCG system will remain in its partially or completely shutdown mode until the operator physically restarts it.

1. Loop 2041: This loop measures the steam flow to the ejector. The flow is recorded on the control system. If the steam flow falls below a minimum of 280 lb/hr, the NCG system will automatically vent the gas stream to the atmosphere at the source.

2. Loop 2042: Control valve GHV-2042 is an on-off valve which allows steam to flow to the NCG ejector. It is a switch operated function in the control system.

3. Loop 2044: This loop measures the steam pressure to the ejector, and the pressure is recorded in the control system. The ejector will not perform properly if the steam pressure is reduced much below its design pressure. Design steam pressure is 160 psig. Ejector performance is critical to safe operation of the system. The steam pressure is interlocked and the NCG system will automatically vent the gas stream to the atmosphere at the source if the steam pressure falls below a preset level (130 psig).

4. Loop 5046: This loop controls the flow of white liquor to the Gas Scrubber. The controller acts through control valve KFV-5046 on the White Liquor Supply Pump discharge to maintain proper flow to the Gas Scrubber.

5. Loops 5048 and 5051: These loops contain a vent valve and shutoff valve for controlling the direction of NCG flow. The position of the vent valve is always opposite that of the shutoff valve. The vent valve opens and shutoff valve closes so gases can be vented. They reverse positions when the noncondensible gases are collected. The failure position is such that the gases will vent.

6. Loops 5049, 2074, and 2079: These loops are pressure switches that indicate high pressure near each rupture disc. The switches are interlocked so that an alarm will vent the gases at the source. Pressure switches are set at 7 psig. Rupture discs are designed to burst at 10 psig.

7. Loop 5054: This loop measures differential pressure across the Gas Scrubber. An alarm is tripped if the differential pressure exceeds 10" W.C. This indicates the Gas Scrubber has plugged.

8. Loop 5058: This loop controls the exit temperature of the NCG out of the LVHC Gas Cooler. Control valve KTV-5058 adjusts the cooling water flow out of the LVHC Gas Cooler to maintain a temperature of 120°F in the NCG going to the ejector.

9. Loop 2059: This loop controls the amount of vacuum the ejector will pull on the source. The control valve will throttle the noncondensible gas flow to maintain the desired vacuum. The set point should be adjusted to produce a vacuum condition near atmospheric pressure at the source. In-line manual valves can be used to assist in this goal.

10. Loop 5060: This loop controls the level in the lower channel of the Gas Scrubber. The controller acts through control valve KLV-5060 on the White Liquor Return Pump discharge to maintain proper level in the Gas Scrubber discharge.

11. Loop 5067: This loop controls the level in the Digester Area Foul Condensate Tank. The controller acts through control valve KLV-5067 on the Foul Condensate Transfer Pump discharge to maintain proper level in the tank.

12. Loop 2070: This loop measures the NCG flow from the Blow Heat Recovery System. The flow must be above a minimum, 200 ACFM, for the system to operate safely. Therefore, this flow is interlocked so that if a low flow condition occurs, the NCG system will automatically vent the gases to the atmosphere through the powerhouse area vent. (including steam flow from ejector)

13. Loops 2072, 2075 and 2080: These loops are similar to the vent/collect loops 5048 and 5051, except they are located on the NCG line downstream of the steam ejector. This is the last opportunity to vent gases prior to the incineration point. There are two shutoff valves in the loop, one for the Riley Bark Boiler and one for the C-E Bark Boiler. Only one of the two shutoffs is able to open at a time depending on the position of the incineration selector switch in the control system.

14. Loops 2077 and 2082: These loops are temperature switches on the NCG lines near the incineration points. Set at 350°F, the switches are interlocked to vent NCG if a high line temperature is detected near the nozzle. A high temperature would indicate a possible burning or flashback condition inside the line.

15. Loop 2083: This loop is a flow element which reduces high pressure steam to 5 psig as required for steam purge for both the Riley Bark Boiler and the C-E Bark Boiler.

16. Loops 2085 and 2086: These loops automatically allow steam to purge the NCG line for 60 seconds after gases are vented by Loop 2072. Steam enters the line just downstream of the shutoff valve and pushes the remaining NCG into the incineration point. GHV-2085 is located in the Riley Bark Boiler area while GHV-2086 is located in the C-E Bark Boiler area.

17. Level gauges:
Two local level gauges are included in the system. These are included to assist in field inspection of the performance of the system as well as to check against the control room instrumentation.

Loop No.	Location
KLG-5066	Gas Cooler
KLG-5087	Gas Scrubber

18. Pressure Indicators:
Twelve local pressure indicators are included in the system. These are included to assist in field inspection of the performance of the system as well as to check against the control room instrumentation.

Loop No.	Location
GPI-2043	Steam Inlet to Steam Ejector
KPI-5045	White Liquor Supply Pump discharge
KPI-5053	NCG at Blow Heat Secondary Condenser
KPI-5056	NCG outlet from Gas Scrubber
KPI-5061	White Liquor Return Pump discharge
KPI-5063	Cooling water into Gas Cooler
KPI-5064	Cooling water out of Gas Cooler
KPI-5068	Foul Condensate Transfer Pump discharge
GPI-2071	NCG Outlet from Steam Ejector
GPI-2076	NCG at Riley Bark Boiler
GPI-2081	NCG at C-E Bark Boiler
GPI-2084	Purge Steam to boilers

19. Temperature Indicators:
Seven local temperature indicators are included in the system. These are included to assist inspection of the performance of the system as well as to check against the control room instrumentation.

Loop No.	Location
KTI-5047	White Liquor Supply Pump discharge
KTI-5052	NCG at Blow Heat Secondary Condenser
KTI-5055	NCG outlet from Gas Scrubber
KTI-5057	NCG Outlet from Gas Cooler
KTI-5062	White Liquor Return Pump discharge
KTI-5065	Cooling water out of Gas Cooler
GTI-2069	NCG Outlet from Steam Ejector

K. Incineration Nozzles (O-1003, O-1004)

The incineration nozzles are designed to inject the noncondensible gas into the boiler's main flame.

L. Digester Area Foul Condensate Tank (353)

This tank is designed to accept foul condensate from both the Strong and Dilute NCG Gas Coolers. The foul condensate is then pumped to the existing foul condensate stripping system. The tank is vented back to the suction side of the steam ejector.

1. Foul Condensate Transfer Pump (365)
This pump accepts foul condensate from the Digester Area Foul Condensate Tank and pumps it to the existing foul condensate stripping system.

IV. DESIGN BASE

LVHC Noncondensible Gas Sources

Blow Heat System	460 ACFM at 140 °F

Gas Scrubber

Liquor Temperature	190 °F
Liquor Flow	80 gpm
Gas Inlet Temperature	140 °F
Gas Outlet Temperature	926 ACFM
Gas Outlet Temperature	185 °F

Gas Cooler

Gas Inlet Flow	926 ACFM
Gas Inlet Temperature	185 °F
Gas Outlet Flow	404 ACFM
Gas Outlet Temperature	120 °F
Moisture Condensed	2.2 gpm
Water Flow	86 gpm
Water Inlet Temperature	90 °F
Water Outlet Temperature	120 °F

Steam Ejector

Gas Inlet Flow	404 ACFM
Gas Inlet Temperature	120 °F
Steam Flow	455 lb/hr (preliminary)
Steam Pressure	150 psig

Bark Boilers

NCG Flow	655 ACFM at 170 °F (after ejector)

V. START-UP PROCEDURES

A. System Inspection

Visual inspection of the noncondensible gas system should be performed at the initial start-up, after extended shutdowns, and after significant maintenance operations. The operators should visually check as much as possible that the system is functionally sound and complete in order to minimize any problems that may occur.

1. Piping

   Mill personnel should walk the piping routes to insure that all of the lines are connected, rupture discs have been installed, all of the valves are in place, the piping hangers are in place, and the flanges are connected. If any discrepancies are noticed, the system should not be started until the problems are corrected. The piping should be pressure tested before the initial start-up.

2. Instrument Air Lines

   The pneumatic air lines are vital to the proper operation of the system. Mill personnel should insure as much as possible that the instrument air lines are connected to air sources and the block valves located near each of the automatic valves are in the "open" position as required.

3. Steam Ejector

   The ejector should be inspected to insure that it has been properly installed. Operators should verify that the steam connection is to the 160 psig supply.

4. Distributed Control System

   To the maximum extent possible, all safety interlocks should be verified for proper functioning through the DCS prior to actual introduction of NCG into the system.

B. System Set-Up

1. Perform the system inspection as previously described. NCG should be venting to the atmosphere.

2. The operators should verify that noncondensible gases are available from the source. If noncondensible gases are not available the operator should leave the vent open until gases become available.

3. Open the manual valves for the system instrumentation including the flow elements, pressure indicators, pressure transmitters, and pressure switches.

4. Open the manual valves on the NCG line.

6. Open the manual valves on the steam to the ejector and the steam purge line.

7. At this point, all manual valves in the system should be open.

C. Gas Scrubber and Gas Cooler start-up

1. Fill the seal loops on both vessels by opening the fill water valves.

2. Start seal water for both white liquor pumps.

3. Start the white liquor circulation through the scrubber by turning on the White Liquor Supply Pump and manually opening flow control valve KFV-5046 until a flowrate of 20 gpm is achieved. Once a liquor level in the bottom of the Gas Scrubber is detected using the level gauge, start up the White Liquor Return Pump. Set the level controller at 60% and switch the control to automatic. The level control valve KLV-5060 will then automatically maintain a constant operating level in the Gas Scrubber. Set the Flow controller to 20 gpm and switch it to automatic.

4. Bring the Gas Cooler on-line by manually opening temperature control valve KTV-5058 to fill the cooler with cooling water. Once filled, set the temperature controller to 120° F and switch it to automatic.

NCG Collection

1. Set the pressure controller GPV-2059 for 15" W.C. vacuum and switch to automatic.

2. Start the steam flow to the NCG ejector by opening GHV-2042 with panel switch. Pressure control valve GPV-2059 should throttle to maintain the desired vacuum.

3. Begin collecting the NCG from the Blow Heat Recovery System. The NCG will now be collected from the source, be pulled through the piping by the ejector, pass through the Gas Scrubber and Gas Cooler and vent to the atmosphere.

D. NCG Incineration

1. Verify that block valves on NCG lines into the incineration points are open.

2. Select either Riley Bark Boiler or C-E Bark Boiler for incineration.

3. When ready, switch loop 2072 from vent to burn by pressing the burn button. Gases are now being incinerated in the selected incineration point.

Note: In order for any of the NCG to burn in the incineration point, all of the safety interlock permissives must be satisfied. Any failures in the permissives will automatically close all of the shut-off valves and open the corresponding vent valve.

4. Manually closing the shut-off valves will automatically open the corresponding vent valve.

VI. CONTINUOUS OPERATING PROCEDURES

Once the noncondensible gas system is started, very little attention need be devoted to it by the operators other than routine inspection of the burner control panel. Some points of attention in the continuous operation of the noncondensible gas system are:

A. Valve Cycling

During long periods of continuous operation, the automatic control valves in the system should be cycled once a month to insure proper operation when needed. The opposite position need only be held long enough to insure that the valve has gone through a full cycle.

B. Controllers

The operators should routinely monitor the ejector steam pressure, NCG flow and NCG pressure to verify these controllers are operating normally and that the process variables are in the desired range.

C. Flame Scanning System

The noncondensible gas system uses the flame scanning system for the Riley Bark Boiler and C-E Bark Boiler. The operators should be familiar with its operation. The scanner is connected to the control system so that if the flame goes out at the incineration point, the noncondensible gas flow to the incineration point will be stopped and the gases will be vented to atmosphere.

D. Flashback Alarm System

The flashback alarm system provides for the automatic shutdown of the system in the case of flame or overheating NCG line at the incineration point. The alarm is activated at 350°F. A flashback will cause the noncondensible gases to be vented to the atmosphere. When the temperature falls below 350°F, the system can be returned to operation by pushing the appropriate buttons. The most likely cause of a flashback will be low gas volume or high pressure at the incineration point. Low gas volume reduces the velocity at the incineration nozzle. High pressure at the incineration point allows the flame to burn back up the nozzle. It is unlikely any damage will be caused before the alarm is activated.

E. Gas Scrubber

The gas scrubber should be periodically checked for pressure drop and washed with water every six months.

It is recommended that all equipment in this system be checked for proper functioning at least once per year.

VII. SHUTDOWN PROCEDURES

A. Temporary Shutdown

A temporary shutdown, either for an emergency or for an operating reason, may be accomplished by turning the NCG "vent-accept" switch at the powerhouse or the "vent-collect" switch in the digester area to the "VENT" position. This will safely vent the NCG to the atmosphere.

B. Extended Shutdown

The following procedure should be used for an extended shutdown of the NCG System:

1. Turn the NCG "vent-collect" switch in the digester area to the "VENT" position.

2. Turn off the steam supply to the steam ejector.

C. System Maintenance

If maintenance work is to be performed on any part of the system, close and lock the appropriate hand valves to isolate the area to be worked on. Blanks should be installed in the piping to provide additional protection. Caution should be used whenever breaking open a noncondensible gas line as toxic gases may be present. Be sure to purge any line or piece of equipment prior to working in or on it. Test for combustibles before welding on any part of the system. To purge the system prior to maintenance, follow these steps:

1. Vent the source to the atmosphere.

2. Open the purge valve on the NCG line at the source. With the ejector still in operation, air will be pulled through the open valve by the ejector.

3. Allow lines to purge at least 20 minutes.

4. Close GHV-2042 to shut off steam to ejector.

5. Use manual valves and blanks to isolate area where line maintenance is to be done.

VIII. TROUBLESHOOTING PROCEDURES

Generally speaking, sufficient information is present in the control system to adequately troubleshoot the noncondensible gas system and indicate what field corrections are required.

The alarm system is to alert the operators when a field problem occurs. At the start of a field problem, the appropriate alarm will activate.

The audible alarm can be silenced by depressing the "Acknowledge" button. Once the field condition is corrected, the system can only be restarted after resetting the system and then selecting "Collect" in the control system .

Requires operator follow-up to minimize vent duration.

Most of the alarms are self-explanatory. The brief troubleshooting table below will assist new operators in responding to alarms. It is important to stress to new operators that if they have any situations occur that they are uncomfortable with, the system may be vented at the source until the situation is resolved.

Certain problems can cause the system to perform poorly without causing a shutdown. These types of problems include low steam pressure available to the ejector or poor quality (wet) steam.

Alarm	Possible Causes, and Correcting Action
Low steam pressure or low flow to the ejector.	Check for loss of steam supply, closed manual valves, closed automatic valve, or ejector problems.
Low combined NCG flow.	Not enough NCG volume to produce safe line velocities. Increase NCG volume. Check ejector steam flow. Steam flow should be sufficient to achieve safe NCG line velocity.
High pressure near any rupture disc.	High pressures are generally caused by fires, explosions, or closed manual block valves. To determine if the rupture disc in question has burst, it can be physically examined or valved out and pressure tested to about 3 psig. Sometimes a ruptured disc can be identified by vapor venting from the disc discharge while gases are vented at the source near the disc. Do not attempt to run system with a broken or missing rupture disc.
Loss of boiler flame.	Check to see if flame was really lost in the boiler. Reestablish flame before attempting to burn gases again. When flameouts are a continuing problem, vent NCG until the situation stabilizes.

Question - will steam ejector produce enough flow to satisfy permissive when no digester blows for a while?
Yes

High NCG temperature in line to boiler nozzle.	Examine line between the shutoff valve and kiln nozzle for evidence of burning. Burning or flashback due to low NCG line velocities are most likely cause of this alarm.
High and low vacuum on ejector suction.	These alarms are informational, alerting the operator that the system pressures are fluctuating. Operator should examine pressure loop GPV-2059 for valve or transmitter problems or controller tuning. Wide or sudden swings in the NCG source conditions may cause these alarms to go off.
Indicator lights on sources and vents not working.	One of the two indicating lights at each source on the graphic panel should be lit at all times except when valves are cycling. If neither (or both) are lit, it is likely that position switches on the valve are out of adjustment.

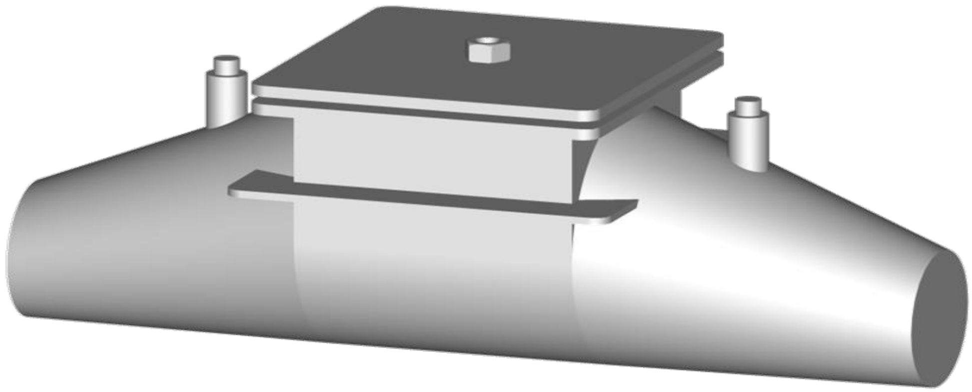
i.e. positive verification of valve position — one open & one closed at all times.

IX. REFERENCE DRAWING LIST

AL-895386-01 Sht. 2/4	LVHC NCG System P&I Diagram
AL-895386-02 Sht. 2/4	LVHC NCG System Line & Valve Diagram

EXHIBIT E

FLAME ARRESTERS



LUNDBERG

FEATURES

- Specifically designed for the pulp and paper industry
- Over 850 arresters installed
- Suitable in VOC, LVHC, HVLC and SOG systems
- Removable heat absorbing pack for ease of cleaning and replacement
- Weld-end or flanged
- 2″ up to 36″ diameter
- Vertical or horizontal installation

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BENEFITS

The collection of TRS and volatile gases in Non-condensible Gas (NCG) and Odor Abatement Systems is an integral part of the pulp mill's environmental program. The flammability of many of these gases presents the possibility of flame propagation in the collection system's pipe lines. The flame arrester is an effective precaution against flame propagation and possible damage to process equipment. To meet the rigorous standards of our NCG Systems, Lundberg developed and supplies a proprietary designed flame arrester.

Since 1977, with hundreds of units installed, Lundberg's Flame Arrester has proven to be a reliable and versatile device for system safety and protection.

LUNDBERG'S AREAS OF EXPERTISE

- ☐ BY-PRODUCT RECOVERY
  - ☐ Tall Oil Soap — ☐ Acidulation — ☐ Storage
  - ☐ Turpentine — ☐ Condensing — ☐ Storage
- ☐ CHEMICAL HANDLING AND STORAGE
  - ☐ Sulfur
  - ☐ Caustic
  - ☐ Acids ____________________
  - ☐ Sulfur Dioxide — ☐ Storage — ☐ Vaporization
- ☐ CHEMICAL GENERATION
  - ☐ Sulfur Dioxide
  - ☐ NSSC Pulping Liquor
  - ☐ Sulfite/Bisulfite Pulping Liquor
- ☐ EVAPORATORS FOR PULPING LIQUOR
  - ☐ Multiple-Effect — ☐ Vapor Recompression
  - ☐ Strong Liquor Concentrators — ☐ Crystallizer
  - ☐ Pre-Evaporation — ☐ REX Technology
  - ☐ Falling Film
- ☐ FOAM CONTROL
  - ☐ Washer Filtrate — ☐ Weak Liquor Storage — ☐ Soap Skimming
  - ☐ Foambreaker for Light Foam
  - ☐ Soap Concentrator for Heavy Foam and Soap
- ☐ HEAT RECOVERY AND UTILIZATION
  - ☐ Blow Heat — ☐ Condensers — ☐ Systems
  - ☐ Pre-Evaporation
  - ☐ Digester Heaters and Circulation
  - ☐ Direct Contact Gas Coolers
  - ☐ TMP — ☐ Hot Water — ☐ Steam Generation
  - ☐ Heavy Liquor Heaters
  - ☐ Waste Heat Boilers
- ☐ LUNDBERG CUSTOM EQUIPMENT
  - ☐ Pressure/Vacuum Relief Valves (PVRV)
  - ☐ Flame Arresters
  - ☐ Jacketed Valves
  - ☐ Lundberg Soap Separator/Soap Skimming Rake
  - ☐ Heat Exchangers — ☐ Heavy Liquor Heaters
  - ☐ SO_2 Gas Fans
- ☐ POLLUTION CONTROL
  - ☐ Black Liquor Oxidation — ☐ Weak — ☐ Strong
  - ☐ Condensate Stripping — ☐ Steam — ☐ Air
    - ☐ TRS — ☐ MeOH / BOD — ☐ COD
  - ☐ Noncondensible Gas — ☐ Collection — ☐ Incineration — ☐ Scrubbers
    - ☐ Strong — ☐ Dilute — ☐ SOG
  - ☐ Direct Fired Oxidizer (DFO)
  - ☐ Plywood Industry — ☐ Heat Exchangers — ☐ Steam Tunnel Condensate Evaporator
  - ☐ Regenerative Thermal Oxidizer (RTO) — ☐ Regenerative Catalytic Oxidizer (RCO)
  - ☐ Wet Electrostatic Precipitator (ESP)
- ☐ SPECIAL SYSTEMS
  - ☐ White Liquor Oxidation — ☐ Air — ☐ Molecular Oxygen
  - ☐ Sulfur Addition – Kraft Liquor
  - ☐ Recausticizing – White Liquor
  - ☐ Ash Treatment Systems – Saltcake
- ☐ TURNKEY
  - ☐ Engineering
  - ☐ Complete EPC

EXHIBIT F

A.H. LUNDBERG ASSOCIATES, INC.

Flame Arrester

The collection of TRS and volatile gases in Noncondensible Gas (NCG) and Odor Abatement Systems is an integral part of the pulp mill's environmental program. The flammability of many of these gases presents the possibility of flame propagation in the collection system's pipe lines. The flame arrester is an effective precaution against flame propagation and possible damage to process equipment. To meet the rigorous standards of our NCG Systems, Lundberg Associates developed and supplies a proprietary designed flame arrester.

Since 1977, in more than two hundred installations, the Lundberg Associates' Flame Arrester has proven to be a reliable and versatile device for system safety and protection.

- Specifically designed for the pulp and paper industry
- Over 850 arresters installed
- Suitable in VOC, LVHC, HVLC and SOG systems
- Removable heat absorbing pack for ease of cleaning and replacement
- Weld-end or flanged
- 2″ up to 36″ diameter
- Vertical or horizontal installation
- No low point for condensate accumulation
- Resistant to plugging
- 316L SS construction

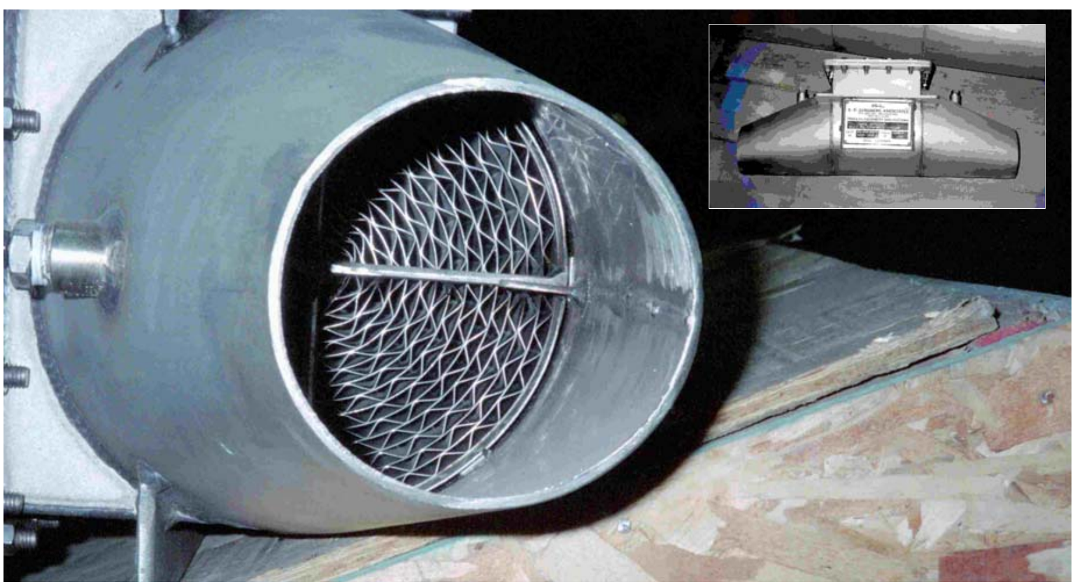

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EXHIBIT G

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ALTERNATIVE EQUIPMENT FOR THE INCINERATION OF NONCONDENSIBLE GASES

David W. Keyser, P.E.

Introduction

In the course of the chemical pulping process, malodorous gases are formed in the digester. These noncondensible gases (NCG) can vent from various process vessels and escape to the atmosphere. Regulations restricting the discharge of these gases continue to be enacted. As mills make their plans for the collection and incineration of NCG, one of the key decisions that has to be made is the determination of where the gases are to be incinerated. This paper is intended to review the various options for incineration of NCG, and discuss the considerations in selecting the incineration method. Advantages, disadvantages, and limitations of each incineration method will be included, as well as safety, process, and cost considerations.

Characteristics of Kraft Pulp Mill Gases

Pulp mill noncondensible gas (NCG) can be generally divided into three categories. One category includes the low-volume high-concentration (LVHC) gases, often referred to as strong gas. Examples of the sources of this type of NCG are:

- Turpentine Recovery
- Blow Heat Recovery
- Evaporator Hotwell / Aftercondenser
- Foul Condensate Storage Tanks
- Continuous Digester Relief
- Steam Condensate Stripping

Another category of NCG includes the high-volume low-concentration (HVLC) gases, often referred to as dilute gas. Examples of the sources of this type of NCG are:

Weak Black Liquor Storage Tanks

Knotter (Screen) Hoods

Brown Stock Washer Hoods

Brown Stock Washer Filtrate Tanks

Brown Stock Washer Intermediate Stock Chests

Brown Stock Washer Foam Tanks

Oxygen Delignification Blow Tanks

Oxygen Delignification Post O_2 Washers

Oxygen Delignification Filtrate Tanks

Oxygen Delignification Interstage Pulp Storage Tanks

Decker Hoods and Filtrate Tanks

Chip Bin Relief Condensers*

Air Condensate Stripping*

** Special consideration must be given to these sources for its potential for containing significantly higher quantities of turpentine vapor and sulfides.*

Environmental regulations over the last 15 to 20 years have typically required that only the SOG and LVHC gases be collected and incinerated. However, with the enactment of more restrictive regulations pertaining to the control of pulp mill emissions, both new mills and some mills with major expansions will be required to collect and control the HVLC gases in many countries.

The flow rates and compositions of the NCG vary with the source process design, the condition of the source equipment, and the wood being pulped. For this reason, the NCG sources must be carefully studied prior to design.

In general, the HVLC NCG from kraft pulp mills can be characterized as wet air, contaminated with TRS compounds (e.g. hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide) methanol vapor, and, in some cases, turpentine vapor as well as other organic compounds. The concentration of these contaminants is typically below the lower flammable limit (LFL) for the actual mixtures of these compounds with air. The exact value of the mixture's LFL will depend on the relative amounts of the various contaminants, and will typically lie somewhere in the range of two to five (2-5) volume percent. Maintaining the concentration of these gases below the LFL is of significant value to the safety of the system, since gases with concentrations below the LFL will not sustain combustion without additional fuel.

The LVHC NCG from kraft pulp mills, on the other hand, consists of high concentrations of TRS compounds and methanol vapor, with insufficient oxygen to sustain combustion. It is desirable to maintain the concentration of the combustibles above the upper flammable limit (UFL), in order to preserve the LVHC gas stream in this inherently safe state. As with the LFL, the exact value of the UFL will depend on the relative amounts of the various combustible compounds present in the gas mixture, although it is typically expected to lie somewhere in the range of 20 to 40 volume percent.

A special category of LVHC gas is overhead vapor from a foul condensate steam stripping system. This vapor is a mixture of methanol, water, and total reduced sulfur (TRS) compounds, and is usually referred to as Stripper Off Gas (SOG). Because of its special composition and properties, it is handled separately from the other LVHC gases. It is important to note that SOG is, unlike other pulp mill waste gases, a condensible gas. Therefore, if it is to be burned as a gas, it must be transported in insulated pipe lines, and must not be cooled or combined with either LVHC or HVLC NCG.

Incineration Options For Noncondensible Gases

A number of options are available for the incineration of the NCG in a kraft pulp mill. These options include a recovery boiler, a power boiler, a dedicated waste gas incinerator, a lime kiln, and a regenerative thermal oxidizer (RTO). The viability of each of these options depends on site-specific considerations, which include the following:

- The volume of the NCG to be incinerated.
- The air flow requirements, relative to the NCG flow, for the incineration point under consideration.
- The regulatory permit requirements for the incineration point under consideration.
- The existence of stack monitoring equipment for SO2 and/or TRS on the incineration point under consideration.
- The existence of flue gas scrubbing equipment for SO2 on the incineration point under consideration.
- The cost of oil or natural gas to be used as either primary or auxiliary fuel for a dedicated waste gas incineration system.
- The availability of high-Btu-value waste gas (especially SOG) to provide the primary fuel for a dedicated waste gas incinerator.
- The physical proximity of the various candidate incineration points to the majority of the NCG sources.
- The availability of a suitable location for the injection of NCG gases into the incineration point under consideration.
- Past experience with the incineration of waste gases in one or more of the candidate incineration points.
- The operational availability factor for each of the candidate incineration points.
- The potential for corrosion in existing air systems and/or leakage of malodorous and noxious gases to the surrounding mill environment.
- The presence of turpentine vapors in the NCG.

Comparison of Various Incineration Options

A comparison of the various options for NCG incineration should take into account the considerations listed above for the specific site. Several typical guidelines can be used to facilitate this evaluation.

1. NCG Flow Rates and Incineration Point Air Flow Requirements

The volume of the HVLC NCG to be incinerated is typically on the order of 10,000 to 40,000 actual cubic meters per hour, or even more, depending on the types of sources being collected and the age and condition of the source equipment. This flow rate is on the order of magnitude of the total forced draft air flow requirement for most lime kilns and many smaller power boilers, and in many cases may even exceed that requirement. For this reason, HVLC NCG is not typically burned in lime kilns, unless the HVLC NCG system is dedicated to only one or a few sources. On the other hand, larger boilers, including recovery boilers, may have forced air flow requirements that are five or ten times the flow of the HVLC NCG, and they are therefore a much better "fit" for the incineration of these gases. A dedicated waste gas incinerator or a RTO can be sized to handle even the highest HVLC NCG flows.

The volume of the LVHC NCG to be incinerated is typically on the order of 500 to 2,000 actual cubic meters per hour, again depending on the types of sources being collected and the age and condition of the source equipment. This volume of gas can be handled by most existing lime kilns and power boilers. It must be noted, however, that the LVHC gas (and especially SOG) has a net positive fuel value, and will, therefore, increase the demand for combustion air within this type of existing equipment.

2. Regulatory Permit Requirements

The regulatory permitting requirements for fired equipment with stack emissions often varies from region to region and even from mill site to mill site. In some situations, the permit granted to existing equipment may allow the incineration of NCG without a re-permitting process. When this is the case, it would favor the utilization of existing equipment for burning the NCG over new dedicated equipment (such as an incinerator or a RTO), which would require an entirely new permit.

3. Stack Monitoring Requirements

Many existing power boilers that use low-sulfur fuels do not have continuous emission monitoring systems (CEMS) for their flue gases. The recovery boiler, on the other hand, normally burns concentrated black liquor, which contains sulfur compounds including TRS. For this reason, the recovery boiler, which normally captures most sulfur compounds in the smelt as useable product, typically has a CEMS to monitor TRS. It may also have a CEMS for S02 as well.

This may favor the recovery boiler over some power boilers for burning of NCG, since it may eliminate the need for additional stack monitoring systems. However, it is not an advantage when comparing the recovery boiler to dedicated waste gas incineration systems, which typically provide effective incineration and flue gas scrubbing through the demonstrated control of furnace temperature and residence time, scrubbing media pH, and scrubbing media flow, without the requirement of an installed CEMS.

4. SO_2 Scrubbing Requirements

Many existing power boilers that use low-sulfur fuels do not have flue gas scrubbing equipment for the removal of SO_2 emissions. The recovery boiler, which oxidizes certain sulfur compounds contained in the black liquor to SO_2, typically does not require such equipment due to the subsequent buffering reactions in the recovery boiler. The burning of NCG in the recovery boiler usually does not increase the generation of SO_2 in the boiler furnace to the degree that the allowable level of SO, for the boiler's stack emissions permit will be exceeded. This is because the mass of sulfur as TRS compounds in the NCG is very small in comparison with those sulfur compounds in the black liquor that will oxidize to SO_2. This characteristic of the recovery boiler eliminates the need for additional SO, scrubbing equipment which might be required for NCG in a power boiler, in a waste gas incinerator, or in a RTO.

5. Fuel Requirements and Availability of High Fuel Value Waste Gas

Since LVHC NCG has a net positive fuel value, little or no additional auxiliary fuel for its incineration is required.

Since the HVLC NCG simply replaces part of the forced draft air that is required by the recovery boiler, the additional fuel consumption required by dedicated incineration equipment, such as a waste gas incinerator or a RTO, is avoided. In comparison to a waste gas incinerator, this advantage may be only slight, if a high-Btu-value waste gas stream, such as SOG, is available for combustion in the incinerator. Those mills with properly designed and operated foul condensate steam strippers will have a methanol-rich off-gas stream that can be used to drastically reduce the consumption of auxiliary fuel, such as oil or natural gas, in the incinerator. The use of SOG as a fuel source for a RTO raises concerns, due to possible difficulties in temperature control of the RTO packed beds.

If the flow of HVLC NCG is very high, then it is quite likely that the SOG fuel source will be insufficient for the operation of a dedicated incinerator. In this situation, it is necessary to compare the fuel requirements to the available waste gas fuel, before a decision with respect to an incineration point can be made.

6. Physical Layout and Proximity to Waste Gas Sources

Dedicated incineration systems, such as an incinerator or a RTO, may be located much closer to the majority of the NCG sources. This could produce a savings in the installed cost of the NCG system that would partially offset the cost of the new incinerator or new RTO. Furthermore, by reducing the length of the collection header, it is possible to reduce the horsepower requirements for the HVLC NCG collection fan and the motive steam requirements for the LVHC NCG ejector. The physical layout of the plant will always be an important consideration.

7. Space Requirements

Since the HVLC NCG flow rates are typically quite high, and the resulting HVLC NCG pipelines to the incineration point are often quite large (on the order of 600 mm to 900 mm), a suitable location that is physically accessible for the injection of the HVLC NCG into the incineration point must be identified before the final decision on the incineration point can be made. It is typically good practice to inject the HVLC gases into the tubular air heater inlet or outlet for some power boiler designs, and into a secondary air duct downstream of the air preheater for the recovery boiler. The individual boiler design must be studied with respect to good mixing of the HVLC NCG with the balance of the boiler air, the avoidance of low points where TRS compounds and/or turpentine-laden condensates could accumulate. The availability of sufficient space for HVLC NCG pipe routing and the HVLC NCG system equipment installation must also be considered.

Due to the relatively low flow rate of LVHC NCG and SOG, and their correspondingly small pipelines to the incineration point (typically 100 mm to 200 mm), it is usually relatively easy to find a suitable location that is physically accessible for the injection of these gases into most incineration points. If the incineration point is a power boiler or a recovery boiler, then it is typically good practice to inject the gases directly into the boiler furnace. These gases should not be mixed with the boiler air in the way described above for the HVLC NCG.

8. Past Experience with the Incineration of Waste Gas

In some cases, a given mill site will already have successful experience with the incineration of waste gases in a particular incineration point. Other considerations being equal or nearly so, this experience of the mill's operations, maintenance, and engineering staff may provide a valid justification for selection of a similar incineration point for the burning of the additional NCG.

9. Availability Factors

Generally speaking, recovery boilers have high availability factors and, if the recovery boiler is not in service, then the remainder of the mill will also shut down within a short period of time. This is an advantage over lime kilns, which are subject to more frequent interruptions in operation. Recovery boiler operations tend to be steady, unlike some power boilers whose rate of firing may fluctuate somewhat with steam demand. These relative advantages, however, are not enjoyed over dedicated waste gas incinerators, which are known to achieve steady operation and 98% availability.

10.Corrosion and Leakage of NCG in Existing Air Systems

The introduction of HVLC NCG into the air supply systems of either recovery boilers or power boilers often raises the concern of potential corrosion in the existing air ductwork or windboxes. It can also raise concerns regarding the leakage of malodorous and noxious gases from corroded ductwork and leaky joints into the surrounding mill environment. These concerns can be effectively addressed by ensuring that the gases are both dry and superheated before their introduction into the boiler air system, and by verifying and maintaining the mechanical integrity of the air ductwork and its joint gasketing or sealant. Another approach for"dealing with these concerns is to inject the HVLC NCG directly into the boiler furnace, similar to the waste gas injection that is generally done for dedicated waste gas incinerators and lime kilns (and for LVHC NCG in boilers as well). One disadvantage to this approach is the investment required for a sizable boiler tube wall modification. Another disadvantage is that the beneficial dilution, obtained by combining the HVLC NCG with other boiler air, is lost when the HVLC NCG is injected directly into the furnace.

11.Turpentine Vapor from Special Sources

The potential for high levels of turpentine vapors in the NCG of softwood mills can raise safety concerns due to that vapor's high flame propagation speed and low flammable limit (less than one percent) in HVLC NCG. In a fundamental sense, the need to eliminate high concentrations of turpentine vapor in the NCG is a safety requirement regardless of which incineration option is selected. In a practical sense, however, the size of the HVLC NCG system and the actual location of each viable incineration option may affect the determination of how to deal most effectively with HVLC NCG from sources that present a potential for high turpentine concentrations (for example, chip bins and air stripping systems). In a smaller HVLC NCG system, the chip bin gas would not be diluted so much when combined with gases from the other sources. It might be advisable under such circumstances to collect and incinerate the chip bin gas separately from the other HVLC NCG. In this case, it is quite conceivable that the chip bin gas might be burned in one incineration point (close to the chip bin), while the other HVLC NCG might be burned in another incineration point (located more conveniently with respect to the rest of the HVLC NCG sources).

Safety and Operational Considerations

In order to obtain the safe and reliable incineration of the NCG in any incineration point, a number of safety and operational considerations are necessary. In the case of recovery boiler incineration, special consideration is given to the elimination of moisture from all waste gas streams and the introduction of HVLC NCG to the incineration point as a superheated gas without any entrained liquids. This minimizes any concern that the HVLC NCG system could become a source of corrosion in existing air supply systems or of liquid coming into contact with the smelt bed in the boiler.

The following list is intended to provide the reader with generic system design guidelines. However, any actual NCG incineration system will require individualized and detailed scrutiny, and possible additions to this list. In particular, careful planning of the NCG gas pipeline routing must be done to ensure proper sloping of the lines, as well as the elimination of low points in the piping (or the proper drainage of low points when these are unavoidable).

1. As described above in the section "Characteristics of Kraft Pulp Mill Gases," the HVLC NCG sources are those whose combustibles concentrations can be maintained consistently below the LFL. Therefore, the collection of strong (LVHC NCG) sources into the HVLC NCG system must be avoided, since the inclusion of even one strong source creates the potential for pushing the combustibles concentration of the combined HVLC NCG gases above the LFL.
2. The gas lines must be sized to provide safe line velocities above the flame propagation speeds of methanol and TRS compounds. This is especially important for the gas line going to the incineration point. A low gas flow interlock must be provided for this line to ensure that the gases are vented if this safe line velocity is not maintained.
3. For HVLC systems, ambient flow make-up air must be provided on flow control both to ensure a minimum safe line velocity and to maintain a steady flow of gas to the incineration point. This allows the HVLC NCG system to provide a consistent contribution of air to the incineration point, even when the system experiences variation in gas flows from one or more of the sources.
4. Flame arresters provided in the gas lines at every LVHC NCG source and just upstream of where the NCG is injected into the incineration equipment will protect the LVHC sources and the NCG system equipment from damage in the unlikely event of a source of ignition combined with a gas combustibles concentration above the LFL and below the UFL. A temperature transmitter, located between the flame arrester and the gas injection point, provides a high temperature interlock which will cause the NCG system to vent its gases to atmosphere in the unlikely event that burning were to occur at this point.
5. Entrainment separators are included in the NCG system both to serve as low point drains and to eliminate liquid droplets entrained in the gas stream. The condensate collection tanks for the entrainment separators as well as any other low point drains are monitored with level switches or transmitters. This instrumentation provides high level interlocks which vent the NCG system gases whenever the liquids are not removed properly. These provisions are especially important for incineration of the NCG in the recovery boiler, since the introduction of liquids to the boiler furnace must be strictly avoided.

6. A gas heater is included in the HVLC NCG system to superheat the gas before it is injected into the forced draft air stream going to either the power boiler or the recovery boiler. This accomplishes the same preheating that is required for the forced draft air for which the HVLC NCG is substituted. It also ensures that the HVLC NCG is free of liquid moisture, by preheating the gas to a temperature well above the dewpoint. In addition to addressing the safety of the installation, the preheating prevents the corrosion that would otherwise occur, particularly in the boiler's air supply system. The gas heater may be of either shell-and-tube or steam-coil design. A low temperature interlock for the HVLC NCG at the point of injection into the boiler will vent the HVLC NCG until a minimum gas heater outlet temperature is obtained. The HVLC NCG system vent at the boiler is located downstream of the gas heater. This allows the gas temperature to be re-established while venting the HVLC NCG.

7. A rupture disc, provided in the gas lines at every LVHC NCG source and near the NCG incineration points, will protect the LVHC sources and the NCG system equipment from damage in the unlikely event of high pressure due to a fire in the NCG lines. The system also includes a pressure switch located near each rupture disc with an interlocked high pressure alarm that will vent the NCG whenever the gas line pressure near the rupture disc approaches the burst pressure of the disc.

8. A combustibility meter, used to detect the percent of LFL in the HVLC NCG can be used to alarm at a given concentration, or can even provide an interlock that vents the system when the combustibles concentration in the HVLC NCG becomes too high. In order for such an interlock to be effective, it is necessary to install the meter(s) near the source or sources which may be expected to experience high combustibles concentrations, and then vent the combined system HVLC NCG near the incineration point on high percent LFL.

   These meters have been used successfully at a number of mills. They do require regular calibration and maintenance in order to obtain reliable results and to avoid nuisance trips. Assuming that they receive the appropriate attention, they can be a useful safeguard. However, they should not be used as substitutes for a design that eliminates high concentrations of combustibles in the HVLC NCG. In a properly designed HVLC NCG system, which incorporates the other safety considerations mentioned herein, combustibility meters can be omitted while still maintaining safe HVLC NCG collection and incineration.

9. Chip bin vents present the potential for high concentrations of combustibles, including (in softwood mills) turpentine vapors. While it is true that the chip bin's NCG combustibles are diluted significantly when combined with gas from other HVLC NCG sources, additional system safeguards are necessary in order to avoid combustibles concentrations in excess of the LFL in the combined HVLC NCG going to the incineration point. It is therefore important that the operation of the chip bin, as well as the handling of its vent gas, be designed to eliminate high combustible concentrations due to vapor "blow-throughs" or other chip bin upsets. This will require stable operational levels and temperatures in the chip bin, an adequately-sized chip bin relief condenser, and an interlock that vents the chip bin source to the atmosphere on high temperature at the chip bin relief condenser vent.

   The design of the chip bin itself, as well as the control strategy for the pre-steaming of chips in the bin, will also affect the determination of safeguards that are required to maintain low concentrations of combustibles in the bin's vent gas.

10. The following list is a summary of the typical interlocked permissives that must be satisfied in order to burn NCG.

- Incineration equipment ready to receive NCG. (This is typically a combination of several conditions; for example, a certain minimum steam production (in boilers), air supply fans running, minimum furnace temperature, and flame safety systems in normal operational status.)
- NCG flow not too low at the incineration point.
- NCG temperature not too high at the incineration point.
- HVLC NCG temperature not too low at the boiler.
- NCG pressure not too high anywhere in the system.
- Foul condensate level not too high in condensate drains and/or condensate collection tank(s) anywhere near the incineration point.
- HVLC NCG blower(s) running.
- LVHC NCG steam ejector operation normal (normal steam flow and steam pressure to the ejector).

The venting of gases from the incineration point may, under certain conditions, be followed by transfer of NCG to a secondary or back-up incineration point. This provision will minimise the total amount of NCG system venting.

Summary

The options available for the incineration of NCGs include a power boiler, a dedicated waste gas incinerator, a lime kiln (for LVHC NCG and smaller HVLC NCG systems only), a recovery boiler, and a regenerative thermal oxidizer (for HVLC NCG systems only). The comparison of the various options for NCG incineration should take into account a number of site-specific considerations, which include the following:

- The volume of the NCG to be incinerated.
- The air flow requirements, relative to the NCG flow, for the incineration point under consideration.
- The regulatory permitting requirements for the incineration point under consideration.
- The existence of stack monitoring equipment for SO2 and/or TRS on the incineration point under consideration.
- The existence of flue gas scrubbing equipment for SO2 on the incineration point under consideration.
- The cost of oil or natural gas to be used as either primary or auxiliary fuel for a dedicated waste gas incineration system.
- The availability of high-Btu-value waste gas (especially SOG) to provide the primary fuel for a dedicated waste gas incinerator.
- The physical proximity of the various candidate incineration points to the majority of the NCG sources.
- The availability of a suitable location for the injection of NCG gases into the incineration point under consideration.
- Past experience with the incineration of waste gases in one or more of the candidate incineration points.

- The operational availability factor for each of the candidate incineration points.
- The potential for corrosion in existing air systems and/or leakage of malodorous and noxious gases to the surrounding mill environment.
- The presence of turpentine vapors in the NCG.

When the appropriate safety and operational considerations are applied to the design of the ff¥iP6 system, these gases can be treated safely and effectively with any of several incineration equipment options at any kraft pulp mill. However, the capital and operating costs for the different options will vary greatly from one mill to another, depending upon the site-specific considerations listed above.

The following table summarizes the typical suitability of various incineration equipment alternatives for waste gases. A "+" or a "—" beneath each incineration equipment alternative indicates its relative suitability for the type of waste gas or gases listed.

Types Of Incineration Equipment

TYPE(S) OF WASTE GAS	POWER BOILER	INCINERATOR	RECOVERY BOILER	LIME KILN	RTO
LVHC	+	+	+	+	-
SOG	4-	+	+	+	-
Low HVLC	+	+	+	+	+
High HVLC	+	-	+	-	+
Low HVLC & LVHC	+	+	+	+	-
Low HVLC, LVHC, & SOG	+	+	+	+	-
Low HVLC & SOG	+	+	+	+	-
LVHC & SOG	+	+	+	+	-
High HVLC & LVHC	+	-	+	-	+
High HVLC, LVHC, & SOG	+	-	+	-	-
High HVLC & SOG	+	-	+	-	-

EXHIBIT H

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COLLECTING AND BURNING NONCONDENSIBLE GASES

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Introduction

Kraft pulp mills are typically characterized by a distinct foul odor. This odor is caused by sulfur compounds, referred to as Total Reduced Sulfur (TRS). These gases are generated in Kraft pulping process. TRS can also be generated in direct contact evaporators, in recovery boilers, and in lime kilns. There are four constituents of TRS gases: hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulfide (CH_3SCH_3), and dimethyl disulfide (CH_3SSCH_3).

TRS gases are emitted from several processes in the Kraft pulp mill. The highest concentrations come from the digesters, evaporators, turpentine system and condensate stripping system. Lesser concentrations are emitted from the brown stock washers, condensate tanks and liquor storage tanks. The vent gases are collectively referred to as Noncondensible Gases (NCG).

The first attempts to contain these odorous gases were in the late 1950's. Initially systems collected and transported all forms of NCG in a single pipeline with a fan as motivation. Additional ambient air was added to ensure the TRS concentrations were below the lower explosive limits. This was not always successful, especially with concentrated gases coming from digesters and evaporators. The results were that many early systems experienced fires or explosions.

In the early 1970's advances were made to keep the NCG undiluted. With the smaller gas volumes steam ejectors could be used to motivate the NCG. These systems virtually eliminated explosions in NCG systems and became the precursor for the present day accepted method for handling NCG.

NCG also contains other pollutants, such as turpentine and methanol. These gases are classified as Hazardous Air Pollutants (HAPs). Environmental Regulations also require the collection and destruction of HAPs.

The steam ejector-based NCG systems have been so successful and reliable that the Environmental Regulations in the United States require all Kraft mills to have NCG systems and to operate them at 99% uptime.

NCG Composition

NCG can be separated into three categories depending upon the composition. These are:

- Low Volume High Concentration (LVHC) NCG, also known as Concentrated NCG (CNCG)
- High Volume Low Concentration (HVLC) NCG, also known as Dilute NCG (DNCG)
- Stripper Off-Gases (SOG)

Chip bin gases (CBG) from the continuous digester are a hybrid category. They are typically collected with the HVLC NCG, but require special handling due to high TRS concentration excursions.

Typical LVHC NCG concentrations are shown in Table 1. These gases come from batch digester blow heat recovery systems, turpentine recovery systems, continuous digester flash steam condensers and evaporator vacuum systems. The actual composition will vary widely from system to system dependent on a number of variables. From time to time the composition will vary within the same system.

Table 1. Typical LVHC NCG Analysis

SOURCE	% TRS (VOL)			% O_2 (VOL)		
	Min	Avg	Max	Min	Avg	Max
Batch Digester	20	50	70	0.5	2.0	5.0
Continuous Digester	12	60	80	1.0	3.0	10.0
Turpentine (Batch)	0.1	2.0	10	4.0	12.0	20.0
Evaporator	1.0	60	70	1.0	5.0	8.0
Combined	10	50	65	2.0	3.0	6.0

It should be noted that in LVHC NCG, the TRS gases and HAPs make up approximately 50% of the volume. The largest component of NCG is air that has been depleted of 50% or more of its oxygen.

The main source of air in a LVHC NCG system is leaks. Some dissolved air is also released from the white and black liquor. The oxygen is depleted by reacting with reducing agents, such as Na_2S, in the liquors that it contacts. The data shown in Table 1 are for a “tight” system.

NCG PROPERTIES

Corrosivity

All forms of NCG, but particularly LVHC NCG, are highly corrosive to carbon steel. Normally the NCG is saturated with water vapor resulting in condensation within the collection system. Some of the TRS gases, especially H_2S and CH_3SH are acidic, and will absorb in this condensate. The combination of this acidic condensate and the oxygen present in the NCG can be very corrosive to carbon steel. Thus carbon steel must be avoided in NCG collection systems.

The methanol and turpentine present in the NCG, along with other minor constituents, are very strong solvents that can dissolve or soften plastics or resin in Fiberglass Reinforced Plastic (FRP) piping. Therefore plastics or FRP should also be avoided in NCG collection systems. Furthermore FRP could easily fail during a fire started by NCG ignition.

Either 304 or 316 series stainless steel has proven to be resistant to NCG corrosion. These are the preferred materials of construction for NCG systems.

Toxicity

NCG is highly toxic and has been responsible for deaths and injuries in the pulp and paper industry. The toxicity of hydrogen sulfide is well known. At 20 ppm it causes irritation of the eyes and respiratory tract. Thirty minutes of exposure at 500 ppm causes severe sickness. Exposure at 1000 ppm for 30 minutes is fatal. The other components of NCG are similarly toxic. TRS concentration in a LVHC NCG system is commonly 100,000 ppm or greater.

Great care must be taken in the design and construction of systems for handling NCG gases due to their toxicity. Gas leaks, especially in enclosed areas, must be avoided. Venting must be controlled such that when there is an upset condition the gases are released in a safe manner well away from personnel. Vent stacks should be as high as reasonably possible and clear of any buildings, platforms and ladders where personnel may travel as well as clear of any ventilation air intakes.

Explosivity

TRS, methanol and turpentine are flammable in the presence of sufficient oxygen. If contained in a pipeline or vessel they can also be explosive. Table 2 shows the combustion properties of the main components of NCG.

Table 2: Combustion Properties of NCG in Air

	EXPLOSIVE LIMITS			
	Lower (% Vol)	Upper (% Vol)	Flame Speed ft/sec (m/sec)	Auto-Ignition Temp °F (°C)
H_2S	4.3	45.0		500 (260)
CH_3SH	3.9	21.8	1.8 (0.55)	
CH_3SCH_3	2.2	19.7		400 (206)
CH_3SSCH_3	1.1	8.0		572 (300)
Alpha-pinene	0.8	6.0	500 (154)?	487 (253)
Methanol	6.7	36.5	1.5 (0.50)	867 (464)

The Lower Explosive Limit (LEL) is the lowest concentration of gas (by percent volume) that will burn when mixed with air. At concentrations lower than this level there is insufficient gas to sustain combustion.

Similarly, the Upper Explosive Limit (UEL) is the highest concentration of gas that will burn when mixed with air. At concentrations higher than this level there is insufficient oxygen to sustain combustion.

Unfortunately, the terms LEL and UEL only explain the situation in theoretical terms. In reality, as emitted, TRS gases are mixed with air that has most of its oxygen depleted. As such, the gases are still not explosive at these points. Figure 1 illustrates this situation.

This figure is based on test data and the assumption that mixed TRS gases, which also contain other combustibles such as MeOH and turpentine, are flammable over the range of 2% to 50% for all combustibles. The exact shape of this curve has not been determined, and will vary depending on the TRS components present.

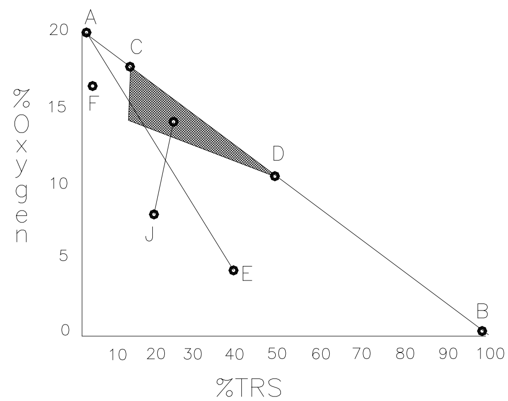

Figure 1. *Explosive Range of NCG*

Point A on Figure 1 is pure air with 21% oxygen, 0% combustible. Point B is pure combustible with 0% oxygen. The two points C and D on Line AB represent the LEL and UEL respectively.

The shaded area under Line CD represents the range of gases that are explosive. For example, Point E represents a typical LVHC NCG mixture that is well outside the explosive range. However, as air is added, the mixture moves along Line AE towards Point A. At some point the gases will enter the explosive range.

In the past, attempts were made to reduce LVHC NCG concentrations below the explosive limit by diluting by a factor of 20 to 1 with air. As a result the mixture ended up at Point F, which is outside the explosive range. However, if the system was under-designed, or if an upset occurred which reduced this dilution ratio, the gases would end up in the explosive range. Once at an explosive concentration an explosion could occur.

Another design concern with NCG is the flame propagation speed. This is a measure of how fast the flame will travel through the pipeline or vessel once a fire is started. See Table II lists velocities for the various constituents.

The flame propagation speed for sulfur gases is relatively slow. The flame propagation speed for turpentine is presently being debated. Some experts claim the value reported in Table II for turpentine is much too high. Regardless, TRS explosions are usually minor with minimum damage. Explosions caused by turpentine can be catastrophic.

It should be noted that the flame propagation speeds listed in Table II are based on pure compounds in pure air.

It should also be noted that while NCG systems are designed to handle the flame propagation speed of TRS. It is not practical to design against the flame propagation speed listed for turpentine. For this reason it is important to minimize the quantity of turpentine entering the NCG system.

Ignition Sources

Three things must be present before an explosion can occur. The first two, namely a combustible material (TRS) and sufficient oxygen, have already been discussed. The final item is an ignition source.

Fans have often provided the ignition source for NCG system fires. This could be from static sparks, hot spots on the casing if rubbed by the impeller, by a hot impeller shaft due to a bearing failure, or by sparks created by foreign material hitting the impeller.

Another potential cause of fire is welding. Lines and vessels containing NCG should be clearly labeled so that they are not accidentally cut or welded upon.

If welding is necessary, all lines or vessels thought to contain NCG should be thoroughly purged and then checked for combustibles before welding is permitted. Care must also be taken to ensure that welding sparks are not drawn in through vacuum relief devices.

As TRS is known to adsorb onto, and then desorb from metal walls, welding should be done immediately after purging and testing for combustibles.

Static electricity can also provide a spark to ignite NCG. All lines and vessels containing NCG must be properly grounded. Otherwise, a static charge may build up, resulting in a spark or static discharge. Several explosions have been traced to this mechanism.

Turpentine can provide a second mechanism for static discharge. If turpentine vapor enters an NCG system, such as during loss of water flow to a turpentine condenser, then some of that turpentine will condense in the piping along with the water vapor also present.

As water and turpentine are immiscible, they will separate in the pipeline. If the interface between the two immiscible liquids is subjected to a shear force, the friction between the two liquids can generate a static spark that can ignite the turpentine.

Such a shear force can occur if these liquids enter a fan or cascade from a horizontal pipe run down a vertical pipe run. Several explosions have been blamed on this mechanism.

LVHC NCG Systems

LVHC NCG comes from both continuous and batch sources. Continuous sources are continuous digesters, turpentine recovery systems, multiple effect evaporators and foul condensate storage tanks. Batch sources include batch digester blow heat recovery systems.

The NCG volumes to be collected vary greatly from mill to mill, and from time to time within each mill. Table III shows the expected ranges of LVHC NCG flow from various sources. It is always best to design on actual test data. If this is not available, then conservative values should be used. Line sizes should be chosen to give a low pressure drop at peak flow conditions. If in doubt as to line size, go larger in the collection lines and smaller for the lines near the incineration points.

Table 3. Concentrated NCG Volumes

SOURCE	FT^3 / TON PULP	M^3 / TONNE PULP
Batch Digester	100 - 200	2.6 - 5.2
Continuous Digester	150 - 300	3.9 - 7.7
Turpentine System (Batch)	40 - 80	1.0 - 2.0
Evaporators	50 - 200	1.3 - 5.2

Note: *Volumes are actual at 60 °C and saturated with H_2O.*

Collected NCG are typically at 60 °C (140 °F) or cooler. If the gases are hotter then consideration should be given to cooling them before transporting them to reduce volume, turpentine content, and moisture content.

Referring to Figure 1, LVHC NCG at Point E are outside the explosive range due to lack of oxygen. Therefore, the system should be designed to prevent ingress of air into the system. This is done by sealing all parts of the system to make them airtight.

However, a sealed system can be exposed to high pressure or vacuum under upset conditions. Most storage tanks or evaporator hotwells are not designed to withstand pressure or vacuum. Therefore they must be protected by both pressure and vacuum relieving devices in order to prevent damage to the vessel during upset conditions.

Keeping the NCG outside the explosive range will insure a safe system at most times. However, during upset conditions, especially during start-ups and shutdowns, it is possible for air to enter the system and create a potentially explosive mixture.

For this reason it is necessary to eliminate all possible ignition sources during the design and operation of the system. Thus steam ejectors are preferred over fans to motivate LVHC NCG.

The vacuum that an ejector pulls varies inversely with gas flow. Thus it is possible to pull a high vacuum under low flow conditions. This may result in a vacuum breaker opening and allowing air into the system. A pressure control valve is used on the ejector suction to overcome this problem.

Steam ejectors have additional advantages. It is possible to size the ejector and the piping downstream of the ejector such that the steam flow to the ejector ensures a line velocity greater than the flame propagation speed of TRS gases, even under low NCG flow conditions.

It should be noted again that it is impractical to design against the flame propagation speed of turpentine. However, steam is an inert gas, and it is possible to design the ejector such that the steam flow will help dilute the NCG to a point outside the explosive range.

Referring once again to Figure 1, if for some reason the NCG coming to the ejector is in the explosive range represented by the darkened triangle, the steam flow may dilute the resulting steam - NCG mixture to Point J. This puts the NCG back out of the explosive range.

To maintain the high NCG line velocity and the steam as an inert gas, it is imperative to keep the steam in the system from condensing. This requires that all steam lines, and all NCG lines after the ejector, be properly insulated to prevent steam condensation.

If a condenser or scrubber is used after the ejector, and the steam does condense, then some other means of ensuring line velocity and dilution should be provided. If not, there is the potential for the NCG to burn back into the transport line whenever the gases get into the explosive range.

Even if care is taken to keep the gases outside the explosive range, and care is taken to remove ignition sources, there is still a remote possibility that a fire may occur. To minimize any potential damage flame arresters should be installed at critical points. They are designed prevent the spread of a fire and to minimize pipeline and equipment damage. Typically flame arresters should be placed at each LVHC NCG source and at each incineration point.

To prevent damage from an explosion in the NCG line, line size rupture discs are installed. Typically, rupture discs have been placed at each LVHC NCG source and near the incineration points. Similar to the placement of NCG vents, care must be used on the placement of rupture discs to ensure that the gases are vented in a safe location if a disc ruptures.

The collection of NCG from continuous sources is relatively straightforward. See Figure 2. The vessels from which the gases are being collected must be kept airtight and properly sealed. Each vessel should be adequately protected from pressure and vacuum and protected by a rupture disc and a flame arrester.

Special attention must be given to overflow lines on these vessels. To avoid the ingress of air they must be sealed. The seal must be sufficient to ensure that pressure or vacuum excursions are relieved through the pressure/ vacuum breaker rather than through the overflow line.

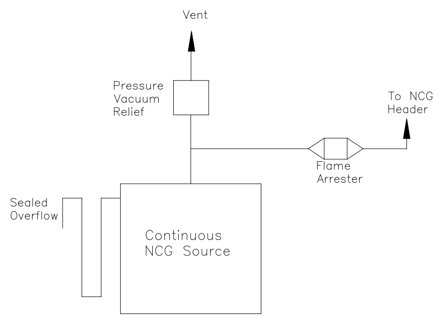

Figure 2. *NCG Collection - Continuous Source*

Additional care must be taken with the collection of NCG from batch digesters. Between blows there is virtually no NCG flow. At the start of a blow there is a momentary high flow. As the blow progresses, this flow decreases until it reaches zero at the end of the blow. In many cases, there is another small peak NCG flow at the end of the blow when the digester blows clean.

In the past, one method to smooth these variations in flow was the use of a gasholder of either a diaphragm or an inverted-bell type. These gasholders were expensive to build, dangerous to operate and difficult to maintain. Gasholders are not used in modern NCG systems.

Batch digester blow heat recovery systems should be operated under positive pressure at all times, to prevent ingress of air. If air gets into the accumulator and condensers, it becomes part of the NCG to be collected. This results in a very high NCG flow and a decrease in condenser efficiency at the start of the blow, invariably leading to venting of steam and NCG to the atmosphere. Also, the addition of oxygen into the LVHC NCG system may create a mixture that is in the explosive concentration range.

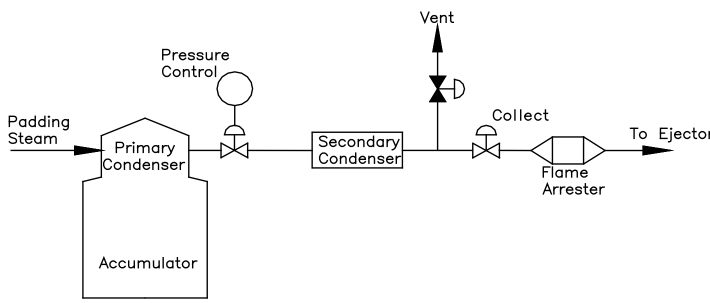

Figure 3. *NCG Collection - Batch Gases*

Positive pressure is maintained in the system by use of pressure control between the primary and secondary condensers. Padding steam is also added between blows to the accumulator, blow tank or condensers to maintain a slight positive pressure. See Figure 3 for the arrangement.

It is essential that the blow heat recovery system be properly sized and operated. If this is not done, the very best designed LVHC NCG system will not be capable of effectively collecting NCG from the blow heat recovery system. Furthermore, it most likely will result in excessive oxygen being added to the LVHC NCG system.

Pressure relief is also required at the blow heat recovery system NCG source. This will prevent large quantities of steam from entering the NCG system and overloading the ejector system if the blow heat recovery condensers fail to perform.

In some systems batch gases are kept separate from continuous NCG sources until downstream of the ejectors. This does not help collect from an improperly designed blow heat recovery system. This adds expense and complication to the NCG system and therefore is not recommended. In a properly designed system a single ejector can be used and gases are combined ahead of the ejector.

Figure 4 shows a concentrated NCG transport system.

Piping Design and Layout

Consideration in the design of NCG systems must be given to the condensates that form in the lines. The NCG are normally saturated with water vapor and some water will condense in the lines. Therefore, it is necessary to slope the lines so that the condensate formed does not build up and block the flow of NCG through the line.

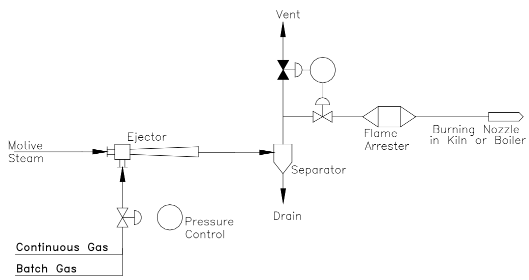

Figure 4. *LVHC NCG Transport*

Low point drains and separators are also required. The condensates formed are very foul and should be collected and treated. They can contain turpentine, which can accumulate and separate into a layer above the condensate.

Special attention also needs to be paid to the layout and positioning of block valves at the incineration point on both the NCG lines and the steam purge lines. Any condensate that collects behind these valves will be injected into the incineration device when the valve is opened. This condensate will be instantly vaporized and could snuff out a kiln or incinerator flame, causing a vent to the atmosphere. In a rarer, but more extreme case, it could cause a minor explosion, damaging the equipment.

Attention must also be paid to the condensate collection system. It must be designed so that it can never be pressurized. If it does become pressurized, condensate can be forced back up the collection lines, and into the incineration device, possibly leading to an explosion.

The motivating steam ejector should be as close to the point of incineration as possible. This results in a majority of the system operating under vacuum. Thus if a leak does occur, it does not result in the release of NCG and the possible gassing of personnel.

A separator or mist eliminator is located after the ejector to remove any water droplets and condensate before the gases are injected into the incineration point.

The NCG then goes through a final flame arrester and into the kiln, boiler or incinerator for destruction. If the kiln, boiler or incinerator are not available for incineration, the gases should be safely vented upstream of the incineration point.

The final consideration is the vent lines. From time to time it will be necessary to vent the gases to the atmosphere. All vent lines should be made as high as practically possible and should release the gases straight up and away from buildings and platforms.

NCG Scrubbing

Some mills have found it advantageous to scrub the TRS from the NCG before the gases are burned. Scrubbing the TRS may be necessary to reduce SO2 emissions if the NCG are burned in a boiler, or an incinerator. In mills where NCG are burned in lime kilns, the additional sulfur may contribute to ring formation in the kiln. Scrubbing the NCG may minimize this problem.

The scrubbing medium is white liquor or caustic solution. The ionizible sulfur gases, H2S and CH3SH, are easily and almost totally removed from the NCG by a chemical reaction. There is insignificant removal of the non-ionizible gases, CH3SCH3 and CH3SSCH3.

When fresh caustic is used as the scrubbing medium it is recirculated to minimize chemical consumption.

When hot white liquor is used for scrubbing, it is normally used on a once-through basis to minimize changes to the liquor temperature and concentration, and to minimize fouling. The NCG is heated up, and must be sent to a gas cooler to reduce the gas volume and reduce condensation in the line following the scrubber.

To avoid the cooler, some mills have used cooled white liquor for scrubbing. However, the heat exchanger used to cool the white liquor is often subject to severe scaling.

Historically packed columns have been used for these scrubbers. Due to the fouling of the packing, particularly when the scrubbing medium is white liquor, spray columns have more recently been employed for this duty with minimal loss of efficiency.

Depending on the scrubbing media used and the NCG streams scrubbed, overall TRS removal efficiencies from as low as 40% to as high as 99% have been reported, although overall TRS removal of about 65% is typical.

HVLC NCG Systems

Sources of HVLC NCG are brownstock washer hoods and seal tanks, knotter hoods, liquor storage tanks, brownstock storage tanks, slakers, mud filters, causticizers and black liquor oxidizers.

HVLC NCG is normally outside the explosive range due to low concentration of TRS (see point F on Fig. 1). HVLC NCG systems are typically designed to run at 25% of the LEL or less. HVLC NCG is normally collected and transported in a common pipeline and motivated with a fan. If the flow is low enough, it is still desirable to use an ejector. Typically an ejector is only practical on a partial system.

As with LVHC NCG, the total volume of HVLC NCG to be handled varies greatly. Flows of between 300 to 900 m^3 per ton (10,000 to 30,000 ft^3 per ton) of pulp are typical.

Brown stock washer hoods on vacuum drum washers are the largest single source of HVLC NCG. It is necessary to properly seal the washer hoods to the vats, and to train the operators to keep the inspection doors closed. Suppliers have developed better fitting hoods to keep the washer hood gases to a minimum. Design volumes for modern, low flow hoods are 1,700 m^3/hr per drum or less.

Newer systems recirculate filtrate tank vents back to the washer hoods in order to reduce gas volume. Similarly, air for air doctors should be taken from the hood to avoid the additional ambient air in the system.

Pressure washers and diffusion washers have much lower volumes of gas to handle.

HVLC NCG collection from large, flat top storage tanks must be carefully designed. In most cases these tanks were not designed to take any pressure or vacuum. When they are tied into a collection system they will be subjected to the system vacuum. These sources often require air sweeps to protect the tankage, however the air sweeps add to the volume of gas to be collected.

As with LVHC NCG, these gases are normally collected at 60°C (140°F) or cooler. In instances where the HVLC NCG is hot and saturated with moisture, coolers are used to reduce their volume, moisture. This has the added benefit of minimizing any turpentine content upstream of the fan if it is present.

Heaters can be used to raise the dilute NCG above the saturation temperature, thus drying them out. Generally they are heated to a point where they are below 50% relative humidity. Having a dry gas is necessary if the gas will eventually go through mild steel equipment such as ducting at the incineration point.

Under no circumstances should LVHC NCG be added to HVLC NCG, especially a LVHC NCG stream that may contain appreciable turpentine vapor.

As in the case of LVHC NCG systems, the pipelines for HVLC NCG systems should be properly sloped and drained. A moisture separator should be installed upstream of the fan suction and near the incineration point. A flame arrester is typically included near the incineration point.

A few mills monitor the concentration of combustibles in the HVLC NCG system to ensure that the gases are always well below the LEL. If the combustible concentration rises above 50% of the LEL during system upsets, then the system is vented or shutdown until the problem is corrected.

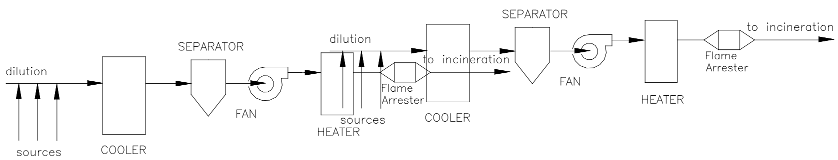

Figure 5. *HVLC System*

Figure 5. *HVLC System*

A system for handling dilute NCG is depicted in Figure 5.

Chip Bin Gas Systems

The gases from continuous digester chip bins are really HVLC NCG, however at times they can contain large amounts of turpentine, VOCs, and TRS. They are typically treated to remove combustible compounds before being transported to an incineration point. The chip bin gases are often handled as a separate stream from the LVHC NCG or HVLC NCG. Most often they are added to the HVLC NCG system after treatment, provided that the HVLC NCG flow is large enough to provide adequate dilution.

In the United States, the Environmental Regulations require the NCG from chip bins to be collected if flash steam is used for steaming. Collection is not required if fresh steam is used for steaming.

Collection of chip bin NCG (CBG) is illustrated in Figure 6. Chips are steamed in the chip bin to remove air before they enter the steaming vessel. This steam can drive volatile compounds, such as turpenes, out of the chips. This situation is aggravated when too much steam is used, or if the steam breaks through the chips due to low chip bin level.

Large quantities of turpentine vapor may be present in chip bin gas. One Kraft mill in the southern United States that pulps pine has reported recovering up to 1 kg of turpentine per ton (2 lb/ton) of pulp from the chip bin gas. Even when only terpene-free wood is being processed, the chip bin gases require treatment due to the excessive volume and high TRS content that may be experienced when steam "breaks through" the chip layer in the chip bin.

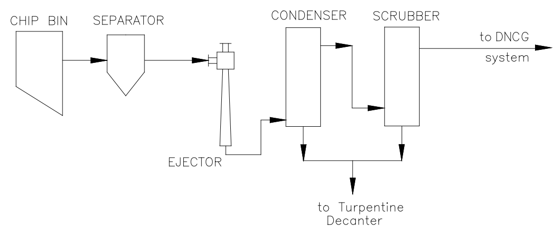

Figure 6. *Chip Bin System*

Proper treatment of chip bin gas includes cooling, condensing and scrubbing to remove as much turpentine as possible. A typical system will include a separator to remove chip fines, followed by an indirect cooler/condenser, followed by a packed column scrubber using cold water.

At temperatures as low as 30°C (87°F) and atmospheric pressure, the vapor pressure of the alpha-pinene fraction of turpentine is high enough to create an explosive mixture. Therefore, dilution air must be added to ensure a safe mixture is being transported. Fans should be avoided when the CBG is handled separately from the HVLC NCG system.

Once the chip bin gas has been cooled, scrubbed and diluted, it can be treated as any other HVLC NCG stream.

Stripper Off-Gas (SOG) Systems

In most cases the stripper off-gas is removed as a mixture of 50% methanol and 50% water, by weight, at about 99°C (210°F). Due to the high temperature and water content of this stream, it must be transported as a separate LVHC NCG system (see Figure 7).

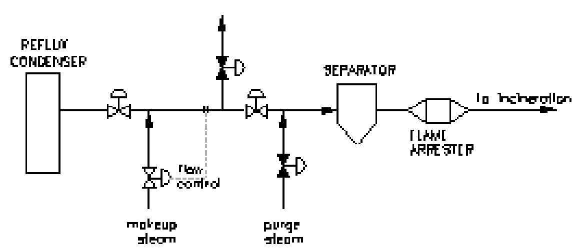

Figure 7. *Stripper Gas System*

The stripper system pressure is typically the motive force to deliver the gases to the incineration point. It is necessary to insulate and heat trace the SOG line in order to prevent condensation.

It is also necessary to steam purge the entire line to remove all air before any methanol rich gas is introduced. This is done by a steam makeup line.

Steam is added downstream of the stripper pressure control valve on flow control by measuring the flow at the incineration end of the line. This ensures a minimum velocity in the line during start-up, shutdown and low flow conditions. As the SOG is very concentrated and noxious, this avoids any venting of the gases during normal operation of the system.

Burning NCG

In order for the TRS and HAPs in NCG to be properly destroyed by combustion, three conditions must be met. These are:

- Temperature of 870°C (1600°F)
- Residence time of 0.75 sec.
- Excess oxygen (O_2) content of 3-4%

These should be considered basic conditions, and if any of them are exceeded, the others can be reduced. That is, if the temperature is higher than 870°C (1600°F), then reducing retention time and/or lowering the excess oxygen content will still provide good destruction. For example, some new, high efficiency kilns are capable of meeting TRS emissions at excess oxygen content as low as 2%.

There are three places in a pulp mill where these conditions exist: the lime kiln, power boiler and recovery boiler. A dedicated separate incinerator can also be installed to destroy NCG.

Lime Kiln

The lime kiln has traditionally been the first choice for burning NCG. It has the advantage that most of the SO_2 formed is absorbed on the lime mud and returned to the liquor cycle.

In many mills the lime kilns are overloaded and have low levels of excess O_2. An overloaded kiln is less effective at TRS destruction.

Modern, high efficiency kilns are designed to run at about 0.5% excess oxygen. This is normally not enough O_2 to completely destroy TRS.

One drawback of using the kiln for TRS destruction is that, in some cases, burning NCG in the lime kiln has contributed to, or accelerated, formation of kiln rings. This is particularly true when the NCG is not burned in a steady manner and the mill experiences poor lime mud washing.

The LVHC NCG should be introduced into the kiln through a separate nozzle, mounted on the kiln hood, to minimize any effect on the main flame. This nozzle must be cooled in order to prevent pre-ignition of the gases while still in the nozzle. In addition, during NCG system shut down with the kiln operating, the cooling jacket prevents heat damage to the nozzle. Air, steam and water have all been successfully used as cooling media. NCG can also be injected through a dedicated port in the main fuel burner of the kiln, although this is not recommended.

The NCG absorbs light in the UV range and can give a false loss of flame signal if they pass in front of a UV flame detector. Thus the NCG nozzle should be placed well away from the flame detectors and at a location that minimizes any interaction with the main flame.

The HVLC NCG is not normally burned in the lime kiln due to its large volume. Smaller HVLC NCG flows may be successfully substituted for primary or secondary air, or added through a dedicated nozzle.

Power Boilers

Boilers have become the most popular incineration point for burning NCG. Due to the relative size of the boiler it is a relatively trouble-free incineration point. However, burning NCG in a boiler will increase the boiler SO_2 emissions, creating another environmental concern.

Further, if the back end of the boiler is less than 160°C (320°F), then H_2SO_3 acid precipitation can occur and severe corrosion may result.

Studies have shown that considerable amounts of SO_2 are absorbed on the ash from coal or bark, if either of these fuels is used in the boiler. This can reduce the SO_2 emitted from the burning of NCG.

The LVHC NCG is introduced into boilers through separate nozzles, similar to those used in kilns. In many cases existing ports can be used for the nozzles. In other cases it is necessary to bend some water-wall tubes in order to place the nozzles.

The NCG flow may be split into two or more parallel lines before entering the boiler. This is done to balance the flow of NCG into the boiler. However, if this is done, great care must be taken to ensure a balance of flow to each nozzle, in order to prevent flame backs due to low gas velocity at one nozzle. The HVLC NCG can be introduced into the boilers as part of the primary or secondary air, or if the flow is small enough, through a dedicated nozzle. Care must be taken when adding or removing the HVLC NCG flow to the boiler in order to prevent upsets in airflow to the boiler.

Recovery Boilers

The recovery boiler is theoretically the best place to destroy NCG as the sulfur gases are destroyed and recovered as Na_2S in the smelt. However, due to the nature of the recovery boiler and its importance in the recovery cycle, the potential for catastrophic explosion due to water entering the unit during operation, or explosive gas build-up during shut down, the recovery boiler has traditionally not been used for NCG incineration.

The Black Liquor Recovery Boiler Advisory Committee (BLRBAC) has recently published “Recommended Good Practice for the Thermal Oxidation of Waste Streams in a Black Liquor Recovery Boiler”. It is available on the BLRBAC Website, www.blrbac.com. The guidelines outline separate methods for burning LVHC NCG and HVLC NCG in recovery boilers. For LVHC NCG this includes the use of a dedicated burner and burner management system with a pilot and auxiliary fuel. For HVLC NCG the guidelines specify that the gases be cooled to 43°C (110°F) to remove moisture and then reheated to at least 66°C (150°F) to result in a gas that is less than 50% relative humidity.

Several mills are now burning LVHC NCG and HVLC NCG in recovery boilers and there is a trend toward accepting this practice.

At a few locations, stripper off-gases are being condensed to a liquid and blended with the heavy black liquor to the recovery boiler.

Incinerators

It is now quite common to burn NCG in a dedicated incinerator. The big advantage of the separate incinerator is that it takes the gases out of a piece of operating equipment and eliminates the complications associated with burning NCG in an operating unit in the mill. Most incinerators use conventional fossil fuel burners, although some are self-sustaining with the heating value of the waste gases being burned and do not require auxiliary fuel except at startup.

The major disadvantage of the incinerator is its high capital and operating cost. These units have been installed as both the primary and secondary incineration points. The trend is away from using the incinerator as the primary incineration point if it is a consumer of fossil fuel. Quick start-up units have been developed as secondary incineration points without the high consumption of auxiliary fuels.

Due to the SO_2 emission, in most cases the incinerator is followed by an SO_2 scrubber, adding further to the capital and operating costs.

Another byproduct of incineration is sulfuric acid mist (SAM) which can give high opacity. Some mills have successfully added additional control devices, such as wet electrostatic precipitators, to reduce SAM.

Recently, some mills have added package boilers to the incinerators to recover the heat from incineration as low pressure steam. The relatively slower cooling of the gases in the boiler results in higher sulfuric acid formation.

Stripper off-gas, due to its high MeOH content, has a very high fuel value and can be used as a primary fuel for incinerators. This reduces the incinerator operating cost by supplying most of the fuel requirement. However, SOG also contains ammonia which can increase NOx emissions from the incinerators.

If the HVLC NCG flow is reasonably low, it may also be burned in the incinerator. In some cases it is substituted for combustion and cooling air to reduce fuel requirements.

Regenerative Thermal Oxidizers

Regenerative Thermal Oxidizers (RTOs) are viable devices for incinerating HVLC NCG. These units generally have a much lower installation costs than other incineration alternatives. They also have very low operating costs and very high uptime. Several mills are successfully using RTOs to incinerate HVLC NCG.

Other Considerations

Several other factors affect the choice of an incineration point for NCG. These are usually site specific. The age, size and operating condition of the locations available are important.

As a general rule, the higher the capacity of the location selected the better as the NCG will have less impact on the operation of the larger equipment.

The uptime of the equipment used to burn NCG is very important. A boiler or kiln that is off line frequently, or for long periods of time, is a poor choice. The Environmental Regulations in the United States require an uptime of 99% for burning LVHC NCG. It is virtually impossible to do this unless there are two points for NCG incineration.

The relative locations of the NCG sources and the point of incineration are also important. This affects the length, and hence the cost, of the pipe line required to carry the gases. Generally shorter piping runs are advantageous.

Impact

Installation and operation of NCG systems has an impact on the rest of the mill operation. The largest impact usually comes from the digester blow heat recovery system.

It is necessary for the blow heat system to collect and condense all the blow steam. Consequently, steam and methanol that were previously vented are now recovered as hot foul condensates. The recovered heat must be reused or discarded.

Many mills are now using recovered blow heat to heat water or pre-evaporate black liquor, while others install cooling towers to remove the excess heat. Also, the methanol collected can increase the BOD load to the effluent treatment system forcing mills to add aeration capacity or install foul condensate stripping systems.

Capturing and burning the reduced sulfur gases in the kiln or recovery boiler, or scrubbing (with white liquor) the TRS gases or the SO_2 formed by incineration, will increase the liquor sulfidity. That may upset the mill sulfur balance, necessitating a change in mill makeup chemicals away from saltcake and toward caustic soda or sodium carbonate.

It may be necessary to update and improve the operation of the turpentine recovery system and the multiple effect evaporators in order to make them compatible for NCG collection. For instance, the practice of bleeding air into the evaporator vacuum system in order to control vacuum is not compatible with NCG collection.

Finally, the places where NCG is burned can no longer be looked upon only as production devices. They must also be considered pollution control devices. It is not uncommon for a mill to run a kiln or a boiler strictly for the purpose of burning NCG, even when the production capacity is not needed.

Conclusion

In order to reduce odorous and hazardous air pollutants from Kraft pulp mills, environmental regulations require that noncondensible gases containing TRS and HAPs be collected and incinerated. These gases are very corrosive, highly toxic, and if mixed with air, potentially explosive.

Consequently, great care must be taken in the design, construction, operation and maintenance of these systems. Fortunately, the technology exists to build NCG systems that are safe, efficient and reliable.

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This paper was originally authored by Mr. Tom Burgess. He had been the instructor for the TAPPI Kraft Recovery Short course since 1986, before retiring in 2005.

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CERTIFICATE OF SERVICE

I hereby certify that on August 12, 2020, I caused the foregoing FIRST AMENDED COMPLAINT to be filed with the Clerk of the Court using the Court's electronic filing system which will send notification of such filing to the person(s) listed below.

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